

# *MISSION REQUIREMENTS FOR A MANNED EARTH OBSERVATORY*

## TASK 1 — EXPERIMENT SELECTION, DEFINITION, AND DOCUMENTATION

Contract No. NAS8-28013

31 May 1973

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## *VOLUME 1*

Prepared for

GEORGE C. MARSHALL SPACE FLIGHT CENTER  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
Marshall Space Flight Center, Alabama 35812

Prepared by

TRW SYSTEMS GROUP/EARTHSAT

**TRW**  
SYSTEMS GROUP

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## FOREWORD

The documentation on the "Mission Requirements for a Manned Earth Observatory" study, performed for the NASA Marshall Space Flight Center, Huntsville, Alabama, under Contract NAS8-28013 resulted in a four volume report. These volumes are:

Volume I	<u>Task 1 - Experiment Selection, Definition and Documentation.</u> Report No. 21324-6001-RU-00, 31 May 1973.
Volume II	<u>Task 2 - Reference Mission Definition and Analysis.</u> Report No. 21324-6002-RU-00, 31 May 1973.
Volume III	<u>Task 3 - Conceptual Design.</u> Report No. 21324-6003-RU-00, 31 May 1973.
Volume IV	<u>Task 4 - Programmatic.</u> Report No. 21324-6004-RU-00, 31 May 1973.

On this study, TRW Systems was contractually assisted by Earth Satellite Corporation, Washington, D. C., and by Model Development Laboratory, Alhambra, California.

The contents of these reports pertain to the mission requirements and conceptual design of Shuttle sortie payloads that could be flown in the 1980s. In developing this information, projections of 1980 sensor technology and user data requirements were used to formulate "typical" basic criteria pertaining to experiments, sensor complements, and reference missions. These "typical" criteria were then analyzed in depth to develop conceptual payloads that are within the capabilities of the Shuttle/Sortie Lab mission capabilities. These payloads, therefore, should not be considered to be potential candidates for Shuttle missions, but only as typical conceptual payloads.

Future studies will be directed more specifically to the development of requirement and conceptual designs for potential Shuttle payloads, such as a Manned Earth Observatory that would be used as a sensor development Laboratory and to accommodate unique data acquisition requirements that would be supportive and complementary to the earth observations automated satellite programs.

Additional information pertaining to this document may be obtained from the NASA Contracting Officer's Representative, Mr. Donald K. Weidner, Marshall Space Flight Center, Huntsville, Alabama 35812.

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## 1.0 INTRODUCTION

This report on Task 1 Study Results is organized in three sections. This section describes the overall study purpose and objectives, the study assumptions and guidelines, and the four study tasks.

Section 2 explains the step-wise progression of study activities and the development of the rationale that led to the identification, selection, and description of earth observation experiments for Shuttle sortie missions. The selected experiments are described, defined and documented by individual disciplines in Section 3. For each selected experiment, the level and degree of documentation follows one of three formats, reflecting the experiment's applicability to:

- a) Early Shuttle sortie reference mission planning, and
- b) The derivation of information needed to accomplish Task 2 – Mission Requirements.

### 1.1 Study Purpose and Objectives

The purpose of the present study is to establish mission requirements and develop a conceptual design of a manned earth observations facility to be used in the Space Shuttle. The specific study objectives are:

- Expand and further define candidate earth observation experiments that are compatible with the Early Space Shuttle Missions
- Identify required sensors (experiment instrumentation) and major supporting equipment and subsystems
- Develop reference missions for the earth observation facility
- Establish the mission requirements associated with these reference missions
- Develop conceptual designs for the required experiment instrumentation and major supporting equipment
- Develop conceptual layouts for the manned earth observation facility and perform systems and operations analyses
- Identify cost, schedule, and SRT requirements.

It is the intent of this study to serve as a focal point in bringing together the most recent results of related earth observations mission studies and programs as they apply to Shuttle sortie missions. In meeting this objective, the products of this study will be:

- Time-phased, problem-oriented experiments
- Representative sample of reference missions
- Reference mission requirements
- Earth observation facility conceptual design
- Earth observation facility scale model

These results will be used to update experimental design concepts to the point where conceptual designs can be formulated for an early manned orbital facility dedicated to multi-disciplinary earth observations.

The information derived in this study will lead to the development and implementation of future programs. To ensure the widest possible consensus of future observational requirements and user's information needs, TRW is supported by Earth Satellite Corporation of Washington, D. C., during the experiment definition and reference mission synthesis phases of this study.

## 1.2 Assumptions and Guidelines

The following assumptions and guidelines will be used during the study. Additional and updated information will be included during the study as directed by NASA/MSFC.

- 1) The Initial Operating Capability (IOC) date for the Shuttle missions shall be assumed to be 1979.
- 2) Operating orbit characteristics should be determined from experiment requirements.
- 3) To the extent that it is compatible with the Space Shuttle/payload carrier operations, the design of scientific instrumentation and support equipment should permit both in-orbit replacement and retro-fitting, and return to earth for possible refurbishment and updating.
- 4) Use of "off the shelf" hardware shall be considered when it minimizes development costs and adheres to the required safety standards.

- 5) This study will not provide for the design of such subsystems as power, communications, data storage, telemetry down-link, environmental control and life support (ECLS), thermal control airlocks, etc., but rather will establish requirements for and on such systems. Support requirements that are termed by NASA to be "excessive" will be made experiment peculiar and will not be considered in this study.
- 6) Launch and Earth return will be by Space Shuttle. Environmental data shall be furnished to the contractor.
- 7) The possible host spacecraft characteristics may change during the course of this study as a result of continuing spacecraft definition activities, such as the Phase B Research and Applications Module (RAM), Phase B Space Shuttle studies and the Shuttle Orbital Applications and Requirements study (SOAR). Coordination with these spacecraft definition studies will be arranged by the NASA COR as required.
- 8) The standard attitude reference position of the Shuttle mounted payload carrier (RAM, Pallet, Sortie Can) configuration will be earth oriented except for limited periods of time within the constraint of the Shuttle attitude control expendables. Further Shuttle constraints will be provided at the beginning of this effort.
- 9) An  $O_2-N_2$  cabin atmosphere of 14.7 psi will be provided with an  $O_2$  partial pressure of 3.1 psi for those areas requiring manned attendance.
- 10) It is assumed that an early austere Earth Observation Facility is to be designed for operation on early Shuttle sortie missions, with growth capability for operation as a Research and Applications Module in Shuttle or Space Station modes.
- 11) The scope of this study is limited to the definition of experiment requirements and techniques, scientific instruments, supporting equipment, experiment data processing, controls and displays, systems and operation analysis, and the identification of the logistics support requirements for the experiments.
- 12) The Earth Observation Facility shall be capable of supporting the general classes of observations contained in the January 15, 1971, edition of the Reference Earth Orbital Research and Applications Investigations (Blue Book), those identified in other studies (completed and on-going), and others identified by the NASA/Contractor/Consultant team during the course of this study.
- 13) All in-orbit maintenance and servicing activities shall be accomplished in a shirt-sleeve environment to the maximum practical extent.

- 14) Use of advanced state-of-art hardware shall be considered when it minimizes development costs and adheres to the required safety standards.
- 15) All materials specified for use in the facility will be non-toxic, non-flammable, and non-explosive to the maximum extent possible.
- 16) A Tracking and Data Relay Satellite System (TDRS) will be available concurrent with the implementation of the Earth Observation Facility. Although availability of the TDRS is probable, the implications of utilizing the existing manned Space Flight Network and other available networks, Intelsat, hard copy data retrieval via frequent Shuttle flights, and other options, should be analyzed.
- 17) Equipment in the pressurized areas must be sized to be compatible with docking port size. Further information will be supplied by the NASA COR as required.
- 18) The latest Shuttle capabilities in terms of orbital altitude and payload weight was provided at the beginning of this effort.

### 1.3 Study Tasks (See Figure 1)

Task 1 — By applying general and specific experiment selection criteria to a list of candidate experiments developed by the study team, potential Shuttle sortie experiments are selected. The Shuttle sortie constraints for early missions (e.g., mission duration, orbital parameters, etc.) are identified and considered in the experiment selection process. The selected experiments are then evaluated for their applicability to early Shuttle sortie reference missions and particularly for their applicability to the derivation of mission requirements. To coordinate the reference mission selection and analysis in Task 2, a tentative rationale for mission selection is established and a reference mission example is carried through the analysis process.

Task 2 — After the tentative rationale for mission selection is further developed, a representative sample of reference missions is selected and analyzed to determine optimal orbits and experiment schedules. These reference missions are then evaluated in terms of commonality, information management/data handling, and a role of man. The results of this evaluation are:

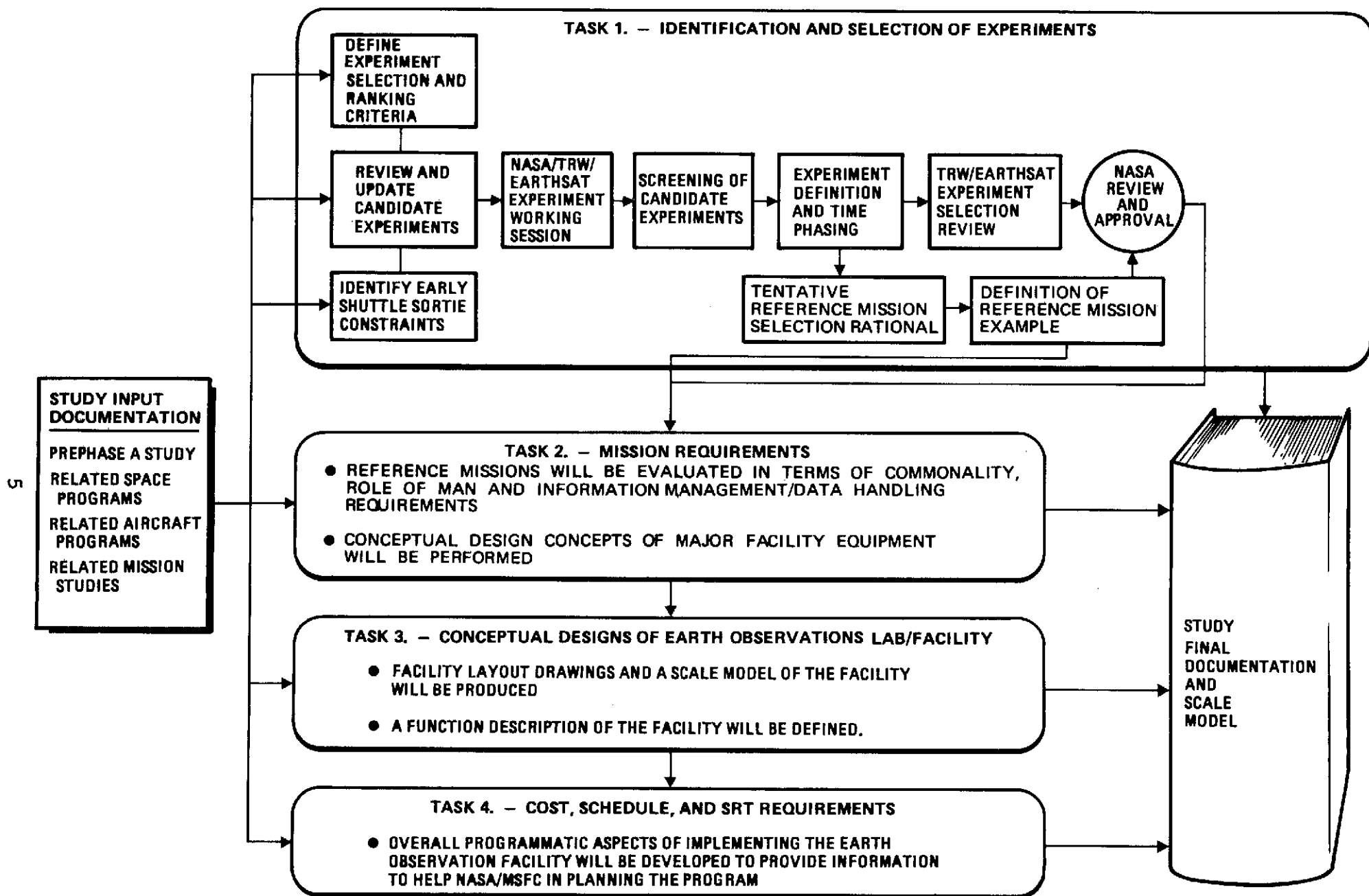


Figure 1. Study Flow Diagram



- 1) The identification of common core and experiment-unique equipment/instrumentation
- 2) Onboard data processing and ground control/data handling requirements
- 3) Recommended uses of man as a direct contributor to onboard experimental activities.

A conceptual design of major facility equipment is also performed in this task.

Task 3 — Once a decision is reached as to whether the sortie is the appropriate carrier for accommodating the conceptual designs of the previous tasks, earth observation facility layouts and configurations are developed. Interface documents are also prepared for the facility to support both interior and exterior equipment/facility arrangements. Crew requirements and supporting logistics are identified for the reference missions described in Task 2. A detailed definition is performed on one of these reference missions. The layout drawings and sketches will be used to construct two 1/48 scale models of the facility.

Task 4 — In this task, the main objective is to develop the overall programmatic aspects of implementing the earth observation facility. Phase A cost data are prepared for the basic facility with its common core equipment and for the mission defined in Task 3. Phase B through D schedules and milestones are prepared for implementation of the earth observation facility. SRT requirements necessary to support the facility's development and the selected reference missions are identified.

2.0 Task I Results  
Experiment Sel. & Doc.

## 2.0 TASK 1 RESULTS (Experiment Selection and Documentation)

### 2.1 Introduction

This section consists of two parts: First, there is a brief summary of the step-wise study activities that led to the identification and selection of experiments. This is then followed by a more detailed description of the rationale that was developed and used to identify, select, and define experiments. Following this, Section 3 presents the experiments in documented format.

### 2.2 Summary

One of the primary products of Task 1 is a set of time-phased problem-oriented experiments that are compatible with early Shuttle sortie missions. The identification and selection of these experiments proceeded by means of step-wise sub-task activities in the following manner:

The study began with a Study Team review and update of earth observations experiment requirements and applications contained in study input documentation. The latter consisted of information on related space and aircraft programs, related mission studies, and the results of work done in the Pre-Phase A MEO study. This activity resulted in the identification of 60 candidate experiments.

Concurrently two parallel efforts proceeded to:

- a) Define criteria (for experiment selection) which could be used to identify those experiments from a candidate experiment list that were best suited for performance in a manned 7-day, low-altitude orbit spacecraft, and
- b) Identify and evaluate early Shuttle sortie constraints to determine the impact of the Shuttle mode of operation on the value and utility of the experimental data.

The Study Team and the COR met at EARTHSAT in Washington, D. C., on 21-22 June for a two-day experiment selection working session. This meeting finalized the experiment selection criteria which were then used to screen the candidate experiments. This screening and experiment selection resulted in a refined list of 54 selected experiments. An

informal presentation of: a) the rationale leading to the selection of experiments, and b) the results of the study to that date, was also made at this time to representatives from NASA Hq.

The selected experiments were then documented according to their applicability to early Shuttle sortie reference missions and particularly for their applicability to the derivation of mission requirements as required in Task 2. The Study Team and the COR met again on 19-20 July at EARTHSAT in Berkeley for a final experiment selection review. At this time the documentation process was finalized and each selected experiment was defined according to one of three agreed upon formats (Levels 1, 2, and 3).

The documentation reflects the time-phasing of the experiments selected, in that those experiments which received full documentation (Level 1) are considered applicable to the initial five years of Shuttle operation. In addition, selected experiments in Level 2 documentation may, when more fully defined and evaluated, also be considered applicable for the first five years of Shuttle operation. The remainder of Level 2 experiments and those making up Level 3 documentation are, at this time, more appropriately considered for the following seven years of Shuttle operations.

The Study Team does not consider that the selected list of experiments constitutes an all-inclusive listing of possible Shuttle sortie experiments. Rather, as interest mounts among the scientific and technical community, a large number of innovative experiments will more than likely be proposed for earth observations Shuttle sortie missions.

### 2.3 Discussion of Rationale Used to Select and Define Experiments for MEO

The Task 1 experiment selection and definition process is shown in Figure 2. The discussion that follows will correspond, element by element, with the corresponding alphabetical designator.

#### a) Candidate Experiments

In the MEO study the earth observation disciplines that were addressed included:

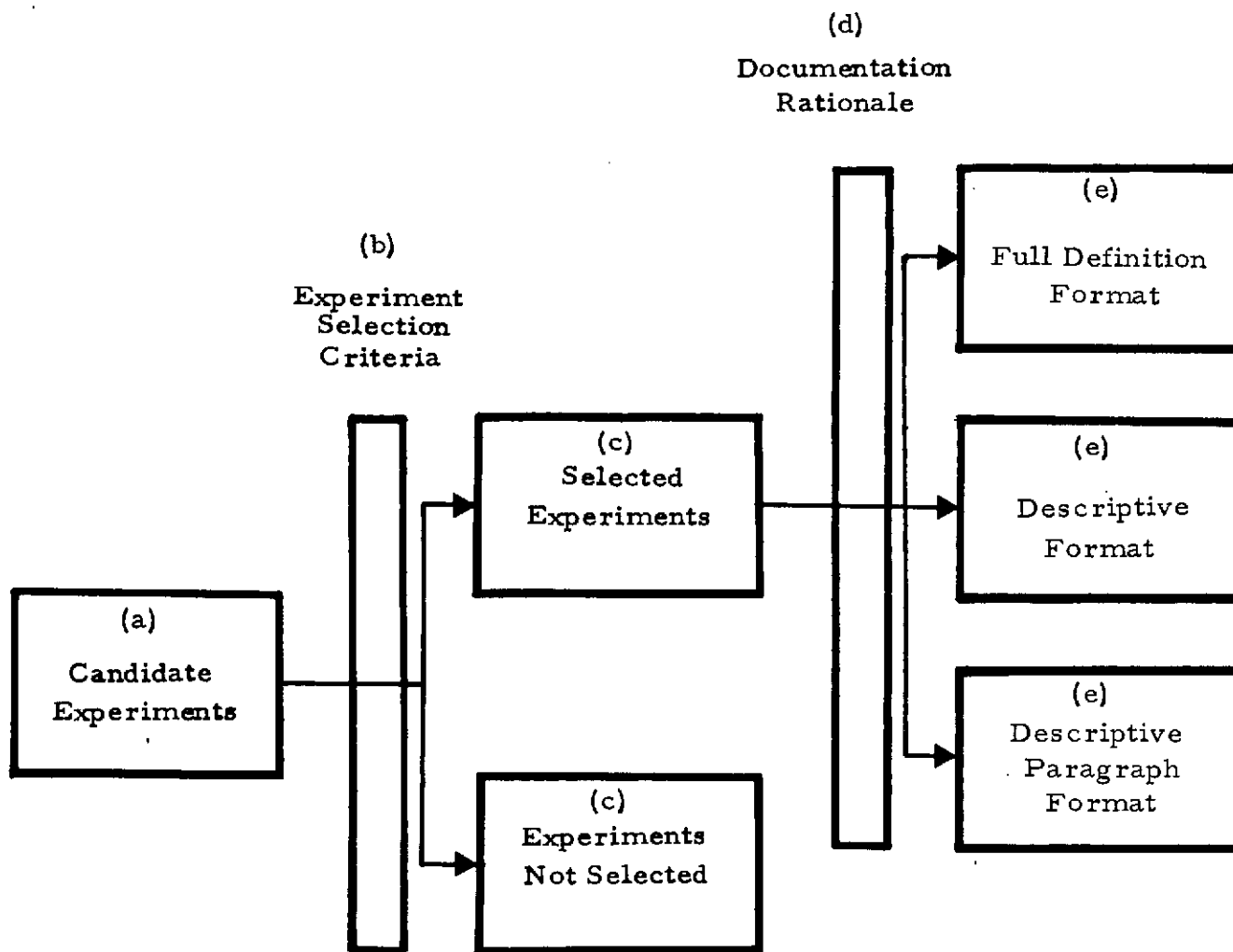


Figure 2. Experiment Selection and Definition Process

- Agriculture, forestry, and rangelands
- Geology
- Hydrology
- Meteorology
- Oceanography.

In addition, special consideration was given to multi-disciplinary problem areas related to:

- Environmental impact of natural and man-induced modification to earth resources
- Others, concerned with archeology, mapping of urban areas, developing countries, etc.

The study team reviewed and updated related earth observations experiment requirements and applications analyses, using as a basis:

- The results of the Pre-Phase A MEO Study
- Reference Earth Orbital Research and Applications Investigations, Volume IV, January 15, 1971 (Blue Book)
- Experiments Requirements Summary for Modular Space Station and Space Shuttle Orbital Applications and Requirements, April 28, 1971 (Green Book)
- Earth Orbital Experiments Program and Requirements Study, Volume 10 and 11, December 1970
- Skylab EREP Experiments Handbook, March 1971
- ERTS A/B and EOS A/B study documentation.

Requirements and applications were assessed in terms of:

- Their relevance in solving specific problems and their benefit to man
- Their compatibility with the constraints of early Shuttle missions
- Their relationship to other ongoing and proposed programs.

Candidate earth observation experiments for manned spacecraft implementation were identified for each of the earth observation disciplines mentioned above. The scientific community was consulted for suggestions on operational and technological needs, and experimental approaches.

This was accomplished through TRW's continuing interaction with various sections of the community and through EarthSat's staff and their consultants, Dr. Robert N. Colwell and Dr. Ronald J. P. Lyon. The results at the end of this reporting period were the identification of 60 experiments, distributed as follows:

Agriculture, Forestry, and Rangelands	8
Geology	5
Hydrology	11
Meteorology	13
Oceanography	13
Environmental Impact	6
Others*	<u>4</u>
Total	60

\*Including Archeology, Urban Mapping, etc.

#### b) Experiment Selection Criteria

Three specific selection criteria filters were developed and defined in order to permit the selection and justification of those candidate experiments that could best be performed in a manned spacecraft, low-altitude orbit environment. The three filters dealt with: 1) Experimental Characteristics, 2) Importance, and 3) Technology, as follows:

##### Experiment Characteristics Filter

Shuttle Sortie Earth Observation Missions are characterized primarily by orbit, mission, and operational flexibility and frequency. By defining two categories, namely:

- characteristics of the Shuttle and automated spacecraft, and
- characteristics of the Shuttle and aircraft,

and allowing an experiment to pass this filter if it requires at least one item in each category, one can establish whether or not the experiment is Shuttle unique. The experiment characteristic filter is shown below:

### Category 1

Can be done by Shuttle or automated spacecraft (not aircraft)

- In orbit
- Above atmosphere
- Geographically remote targets
- Wide area coverage

### Category 2

Can be done by Shuttle or aircraft (not automated spacecraft)

- On-board participation of scientist
- High volume, weight, or power
- High surface resolution
- On-board decisions
- Targets of opportunity
- Precise off-nadir pointing / tracking
- Large data storage
- Short duration

### Importance Filter

The ultimate value of an experiment to the user community and to other programs, as well as the importance of the problems it is addressing, must also be evaluated. The value of each experiment was established by using the following importance filter:

- Does the experiment meet the desires of a large cross-section of the user community?
- Is the experiment valuable in solving specific problems of national importance which are not readily solvable by presently known space or ground-based techniques?
- Will the experiment be useful in developing needed operational systems?
- Is the on-orbit implementation of the experiment compatible with and complementary to experiments planned for other programs?

If the answer to at least one of these questions was positive, then the experiment was considered to pass this filter.



### Technology Filter

This last filter asked the following question: Can the experiment be sufficiently developed to meet the early Shuttle sortie time-line? To pass this filter the answer to all of the questions shown below must be Yes.

- Can the hardware be developed in time?
- Will the analysis techniques be developed in time?
- Does the experiment fall within the anticipated Shuttle constraints on orbit, weight, power, data storage, mission duration, etc.?

### c) Selected and Non-Selected Experiments

The 60 candidate experiments were subjected to a screening process using the experiment selection criteria just described. This screening resulted in the selection of 54 experiments that were deemed potentially applicable to Shuttle sortie missions and the dropping of six experiments from the candidate list because they did not pass the selection criteria process. The selected and non-selected experiments were distributed among the disciplines as follows:

	<u>Selected</u>	<u>Not Selected</u>
Agriculture, Forestry, and Rangelands	7	1
Geology	5	0
Hydrology	9	2
Meteorology	13	0
Oceanography	10	3
Environmental Impact	6	0
Others	<u>4</u>	<u>0</u>
Totals	54	6

\* Early Shuttle Sortie constraints were identified using the following studies: Pre-Phase A MEO, Phase A Comm/Nav, Phase A SOAR, Phase B Space Shuttle and Phase B RAM. The following documents were also used: Space Shuttle Baseline Accommodations for Payloads (MSC-06900), Documentation for Sortie Task 4.1.2.2.1.1 (S&E-AERO-GT-50-72), and Updated NASA Mission Model.

d) Documentation Rationale

The selected experiments were documented according to one of three agreed upon formats which reflected the experiments' applicability to early Shuttle sortie reference missions and, particularly, their applicability to the derivation of mission requirements in Task 2. The three formats correspond to three levels (1, 2, and 3) of experiment description and definition, as follows:

Level 1

- A detailed experiment description and definition format (approx. 6 - 9 pp) which includes: a) experiment objective, background, technical approach, relevancy, role of man, etc., and b) measurement/observation requirements.

This format was used for those experiments that will be chosen for defining sample reference missions in Task 2.

Level 2

- A descriptive format (approx. two pages) which includes the experiment objective, background, proposed technical approach, etc. This format was used to document those experiments that are still considered applicable to early Shuttle sortie missions, but for one or both of the following reasons did not receive the attention accorded to those experiments that will be making up the sample reference missions:
  - a) Full definition of measurement/observation requirements not yet determined at this time, and
  - b) Lower over-all potential importance compared to other experiments.

Level 3

- A descriptive paragraph or two giving a synopsis of the experimental concept. This documentation would be reserved for:
  - a) Experiments for which many important elements remain to be defined, thus making the experiment difficult to evaluate for Shuttle sortie missions, or

- b) Experiments, which in the judgement of the Study Team ranked lowest when compared to other experiments on the basis of their potential importance.

The three levels of documentation for the selected experiments were distributed among the various earth observation disciplines as follows:

	Selected Experiments			
	Level 1	Level 2	Level 3	Total
Agriculture, Forestry and Rangelands	4	1	2	7
Geology	4	1	0	5
Hydrology	6	3	0	9
Meteorology	6	6	1	13
Oceanography	6	3	1	10
Environmental Impact	3	3	0	6
Others	<u>3</u>	<u>1</u>	<u>0</u>	<u>4</u>
Totals	32	18	4	54

e) Documentation Formats

The information required for each level of documentation is given below. Section 3 presents the 54 selected experiments documented according to these formats:

Detailed Description Format (Level 1)

Experiment Title – Short descriptive title; will be needed for quick reference throughout the study. The title will be written in capital letters and preceded by the first letter of the discipline addressed, the number of the experiment, and a period.

## 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

- 1.1 Associated Problem Area(s) – The problem area(s) of the discipline to which the experiment is related. (The problem areas are identified in Pre-Phase A Task I preliminary results document.)
- 1.2 Experiment Objective(s) – Specific Objective(s) and purpose of experiment; significance and importance of expected results; improvements sought/needed; next information to be acquired/derived.
- 1.3 Experiment Background – Background information, relationship to other programs; current status and limitations of observations/information.
- 1.4 Proposed Technical Approach – Textual description of key techniques and scientific/technical procedures for conducting experiment (How will experiment be conducted?), including phenomena/characteristic(s) to be observed or measured and their basic parameters (i. e., accuracy, frequency/rate of measurement, etc.); description of concurrent ground/airborne experimental activities in support of this experiment; indicate how astronaut/scientist participation is essential or desired and how he enhances experiment.
- 1.5 Relevancy of Experiment – Establish relevancy of experiment to information needs for problem area(s) called out in Item 1.1 above. (Pre-Phase A Task I preliminary results document has a non-all-inclusive listing of information needs.)
- 1.6 Role of Man – List man's activities which relate to the experiment (e. g., analysis, assessment of results of data-taking, collateral activities, requirements for unusual sequence of tasks and special skills) and/or to the instrumentation (e. g., preparation, operation, monitoring progress, adjustments, calibration, visual observations, and other measurement-taking).

- 1.7 Impact of Experiment on Shuttle Sortie Mission – Discuss from standpoint of Shuttle-unique characteristics, man's on-line experiment participation, man's post-data acquisition processing and evaluation role and the characteristics of the data that will be gathered.
- 1.8 Supporting Research and Technology Required – Describe relative to such categories as model development, theoretical work, experiments (field, laboratory, etc.) sensor development, data analysis techniques, etc.
- 1.9 Targets – Describe targets in terms of locations and areal extent if targets are preselected; otherwise, indicate as targets of opportunity or general surveillance targets.
- 1.10 Truth Sites – Kinds and their locations if appropriate.
- 1.11 Orbital Parameters – Preferred, acceptable and limiting values for:
  - Altitude
  - Inclination
  - Eccentricity.
- 1.12 Data Required by Investigator – Describe raw data needs, physical format, precision/accuracy, timelines (allowable time from data acquisition to use).
- 1.13 Principal User(s) – List specialist(s), institution(s), organization(s) which will have a use for the data or end information.
- 1.14 Documentation/References – Give any pertinent references relating to the derivation of this experiment (i. e., literature, publications, other communications, etc.).

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

- 2.1 Time of Year/Season
- 2.2 Frequency of Measurement/Observation
- 2.3 Total Time Span of Measurement/Observation
- 2.4 Solar Elevation Angle – Specify optimum and limits, if any.
- 2.5 Cloudiness – Describe, if a problem.
- 2.6 Ground Coverage – Specify area, field of view, and swath width for a nominal altitude of 150 n. mi.
- 2.7 Resolution – Desired and useful limits for parameter geometry (both horizontal and vertical).
- 2.8 Accuracy/Precision – Specify in relation to measurement and measurement location.
- 2.9 Shuttle Instrumentation/Equipment Requirements –  
Listing of experiment-unique and common-core requirements. (The instrumentation/equipment described should be typical of those now under study or development. They will be primarily useful in developing the Facility design. Thus, they should not be construed as being specific instruments or equipments committed to the Shuttle Facility.)

### Descriptive Format (Level 2)

Title – Short descriptive title coded the same as the title in the detailed definition format.

Objective(s) – Same as in detailed definition format.

Background – Discuss relationship to other programs, current status, and limitations of observations/information. Establish the relevancy of the experiment in terms of the problem areas it addresses.

Proposed Technical Approach — Present a textual description of key procedures including phenomena being observed, parameters measured, correlative support used, and the role of man in performing the experiment and interacting with the instrumentation.

Descriptive Paragraph (Level 3)

Title — Short descriptive title followed by the objectives of the experiment and the expected importance of the results.

### 3.0 EXPERIMENT DOCUMENTATION



### 3.1 OCEANOGRAPHY (O) EXPERIMENTS

## SUMMARY EVALUATION

### 01. REGIONAL WATER POLLUTION MONITORING (SAN FRANCISCO BAY AREA EXAMPLE)

Thriving industrial centers located along the coastline, rivers, and estuaries have indiscriminately dumped vast amounts of sewage, industrial sludge, and waste heat into their neighboring waters. This has led to marine ecosystem imbalances, toxic food sources potentially dangerous to man, ruined recreational areas and general aesthetic displeasure. By obtaining high-frequency, high-resolution synoptic coverage of polluted areas, information can be obtained which will lead to improved circulation models as a basis for improved dispersion (i. e., development of improved treatment techniques).

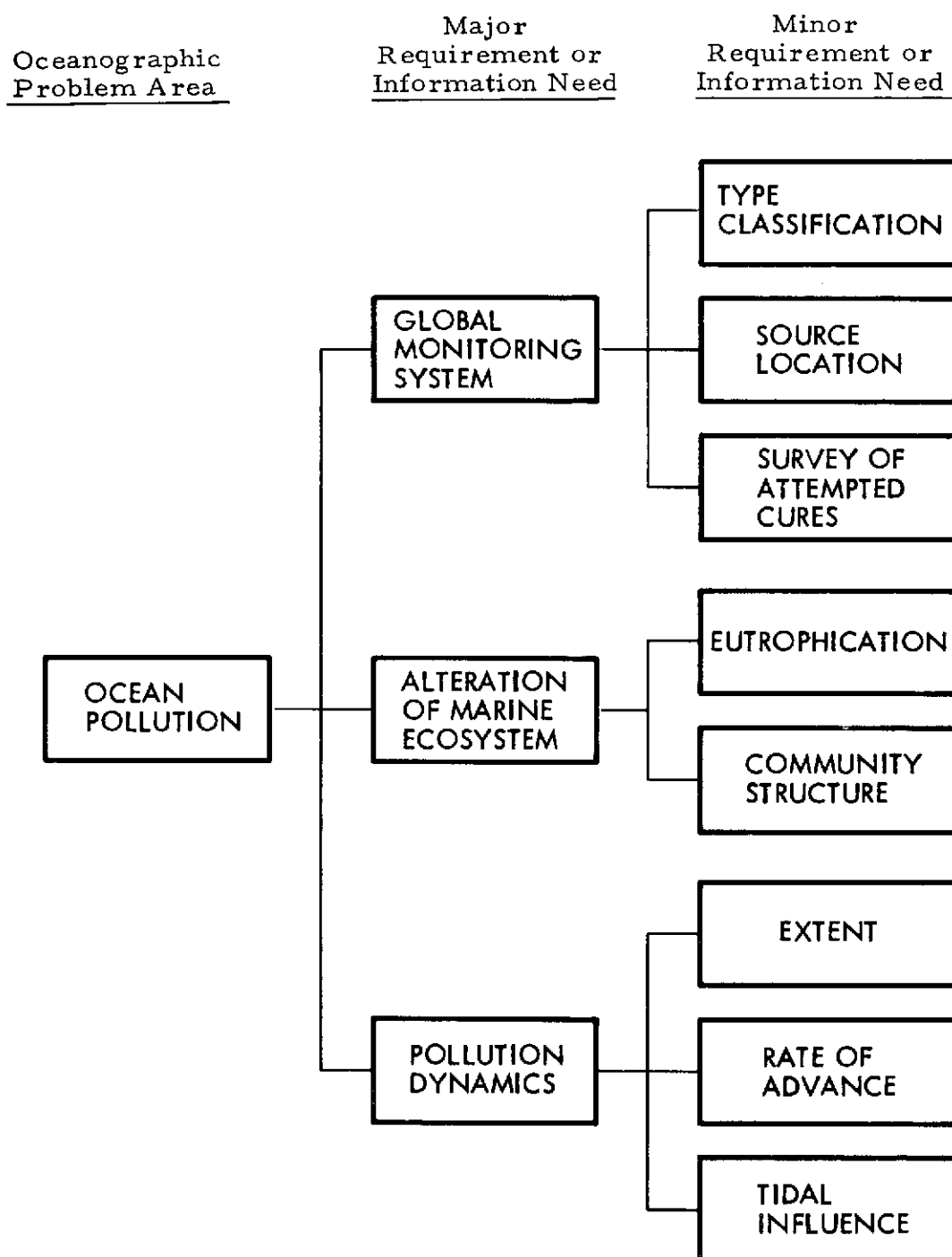
Many localized areas with pollution problems exist throughout the world. Monitoring all of these areas of interest would require an extremely ambitious aircraft program and even if one existed it could not effectively cover some of the larger areas. Unmanned spacecraft, like ERTS, would do a first-look survey of the areas. Through the use of high resolution gimbaled instruments coupled to CRTs, man will investigate targets of interest.

The overall Shuttle (MEO) rating of this experiment is Level 1.

01. REGIONAL WATER POLLUTION MONITORING  
(SAN FRANCISCO BAY AREA EXAMPLE)

1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

1.1 Associated Problem Areas



## 1.2 Experiment Objectives

Provide a basis for global and regional monitoring of pollutants from space by:

- Determination of the effects of wastewaters on the receiving waters
- Measurement of the effectiveness of wastewater management programs.

## 1.3 Experiment Background

Major pollution problems in the Bay area are: toxic wastes, chemicals responsible for bio-stimulation, oil and grease floatables, and pathogenic bacteria. Approximately 700,000 gal/day of relative toxicity are discharged to the Bay system. If the EPA water quality criteria committee recommendations for safe concentrations of toxicants are to be met, a dilution flow of new water of about  $70 \times 10^9$  gal/day would be required (assuming the Bay to be a well-mixed reactor). This is not now available and is less likely to be available in the future. Also of major concern is the effect of nutrients on algae growth (i. e., biostimulation). Based on the amount of nutrients needed to support growth, there is currently an overabundance. The amount of oil and grease floatables currently being discharged into the Bay, mostly from the municipalities, is over 60 tons/day. This is not trivial--assuming 50 percent of the oil and grease is made up of hydrocarbons, a 30 ton/day rate over the course of a year is equal to the recent spill in the Santa Barbara Channel. A discharge of  $\sim 10^{18}$  coliform bacteria/day has resulted in a condition where much of the Bay is heavily polluted from a bacterial standpoint. Few coastal waters meet California Bathing Beach Standards (a coliform concentration of  $<1000$  per 100 ml).

At the request of the San Francisco Bay Regional Water Pollution Control Board, the adverse effects of water pollution on the water quality characteristics and the fishery resources of the San Francisco Bay have been investigated by the Sanitary Engineering Research Laboratory of the University of California, Berkeley, since 1957. The Regional Control Board currently monitors pollution source, type, disposal rate and source treatment on a regular basis.

As the program grows, both in sophistication and scale, water quality and waste discharge monitoring will have to be performed on a

multi-level basis over large geographic areas. In-situ, low altitude aircraft and space platforms will be used in a coordinated effort. Other related research and development programs currently slated for the late 1970s and early 1980s are the Marine Eco-System Analysis (MESA) program (an NOAA program commencing late in 1972), which will study the marine eco-system on a regional scale, and the Earth Observation Satellite (EOS) program (a system of multidisciplinary spacecraft with launches scheduled to begin in 1978). The first region to be studied under MESA is the New York Bight; others include the Puget Sound and the Delaware Bay. By the late 1970s MESA will most likely be investigating the San Francisco Bay. EOS will address the discipline of oceanography, among others, and obtain near global coverage on a 17-day cycle.

#### 1.4 Proposed Technical Approach

The sensing of local instances of water pollution has been accomplished for many years from aircraft using photography and by surface vessels through visual identification of the source and photographic documentation of the spatial extent of the pollution. The last few years have seen a rapid evolution of instruments using other portions of the electro-magnetic spectrum capable of monitoring pollution from a regional to a global scale.<sup>2, 3</sup> With a low orbiting Shuttle, a multispectral complement of these sensors would be trained on a variety of localized areas with pollution problems (e.g., San Francisco Bay)\* to gather data on the following parameters of interest: floatables (e.g., oil slicks), transparency, sea surface temperature, currents, tidal flushing, sea state, and phytoplankton.

Ground support would be accomplished by an in-situ program similar to MESA. Remote observations using aircraft in a manner similar to those obtained by Arvesen and Weaver<sup>2</sup> would also be required. With a real-time communication link between the Shuttle and the ground/airborne experimental activities and real-time data analysis on board the Shuttle, the correlative activities would be deployed in an optimal way.

During an orbital pass of the San Francisco Bay the scientist/ astronaut would participate in the actual operation of the experiment as well as in the analysis of the data obtained. Through the use of a tracking telescope the investigator would recognize complex patterns (e.g., tidal interaction with oil slicks) and conduct precise off-nadir pointing at

\* Note: The detailed description of this experiment will address the San Francisco Bay, but the experiment is aimed at a variety of targets. (See Section 1.9)

targets of opportunity. In addition, he would redirect and schedule the operations of the correlative support to optimally monitor the phenomena of interest. Real or near real-time data analysis and evaluation would be performed by the investigator through the use of the tracking telescope and support equipment such as CRTs and on-board computers. The data will then be screened and possibly compacted for selected transmission to the correlative support and, if required, to ground-based investigators.

### 1.5 Relevancy of Experiment

The San Francisco Bay area exhibits three pollution regions: coastal-zone, estuary, and river delta region. Information on the circulation within these regions is most difficult to obtain. The mechanisms of circulation within the Bay region are tides and currents with some modifying action by the shoreline and bottom topography. These mechanisms are generally monitored indirectly. The information obtained in this experiment can be used to construct an effective means of treatment by leading to improved circulation models as a basis for improved dispersion.

Very little is known about the environment-marine ecosystem interaction. The data acquired in this experiment will supply information about the influence of pollutants on the community structure. This information is necessary if pollution treatment is to be administered without harming the marine ecosystem.

This experiment is a precursor to a fully developed operational system that can be employed in coordinated multi-level multi-national programs to effectively police various water bodies. The experiment is designed to test the ability of a sophisticated monitoring program to classify pollutants by type, distribution, and source. In an operational system these data will be used to estimate the success of ongoing programs attempting to alleviate various forms of pollution or construct an effective means of treatment (e.g., dispersion), and test the ability of a sophisticated monitoring system to gather useful information on the circulation as a precursor for an operational system.

## 1.6 Role of Man

### a) Experiment Activities

- Optimally coordinate the correlative support
- Perform near real-time data analysis using the laboratory available to him
- Observe random targets of opportunity.

### b) Instrumentation

- Detection and location of targets using a tracking telescope
- Pointing and monitoring the instruments slaved to the telescope.

## 1.7 Impact of Experiment on Shuttle Sortie Mission

Crew functions will include the location of cloud-free areas, the selection and use of appropriate sensors and coordination with ground and other airborne activities. Precision pointing of sensors using an observation and tracking telescope will be done manually or may at times be programmed by a computer.

The coverage frequency shown in Table 1 does not take into consideration off-nadir pointing and cloud cover. With the aid of a tracking telescope man could position the sensor subsystem to obtain off-nadir observations of phenomena of interest, thus increasing the coverage frequency. Additionally, with an intrack fore and aft pointing capability the bay could be continuously monitored for a longer period of time. For example, at an altitude of 100 n. mi. with a 45 degree pointing capability the bay could be monitored for approximately a minute.

Table 1. Candidate Orbits

Altitude	Inclination	Coverage Freq.	Advantage
100 n. mi. (Circ.)	Sun-Sync.	Daily	Possible coverage of other US coastal areas for com- parison
100 n. mi.	38°	<u>Several Times</u> Day	Monitor more dynamic phenomena

Because of intermittent cloud cover, the observation frequency will be somewhat less than the coverage frequency. The probability of encountering cloud cover over the San Francisco Bay should be minimized. This requires some consideration with regard to launch date and the time of day the Bay is overflown.

#### 1.8 Supporting Research and Technology Required

- a) Develop instruments capable of meeting the data requirements listed in 1.5.
- b) Conduct aircraft experiments to test newly developed instruments and techniques for acquiring the data.
- c) Develop improved data analysis techniques.

#### 1.9 Targets

Primary: San Francisco Bay and any five of the following sites:  
 Los Angeles Area, Columbia River Delta, Great  
 Lakes Area, Mississippi River Delta, New York  
 Area, Chesapeake Bay, Galveston Bay, Woods Hole  
 Area, Pascagoula Area.

Targets of opportunity.

#### 1.10 Truth Sites

Those acceptable for a MESA program in the San Francisco Bay area.

#### 1.11 Orbital Parameters

	Desirable	Acceptable
Alt.	100 - 150 nmi.	150 - 250 nmi.
Incl.	38° or Sun-Sync.	38° or Sun-Sync.

#### 1.12 Data Required by the Investigator

The data needs of the investigator aboard the Shuttle are as follows:

- Direct high resolution display data for monitoring the area of interest to enable him to coordinate the pointing of the other instruments.
- False color imagery.
- Oscilloscope display of isolines associated with various data needs (e. g., sea surface temperature).



- Instantaneous location of any area the investigator locates with his high resolution monitoring device. This data can then be placed in a computer and used for general pointing in the next acceptable pass.

The data needs of the correlative support on the ground are:

- Appropriate location changes to optimize data taking.

The ground-based investigator/user will only require the data after the Shuttle has returned to the earth.

### 1.13 Principal Users

Organizations:

- NOAA — National Marine Fisheries Service  
— MESA Project
- EPA — Water Quality Office, Standards and Enforcement, Planning and Management, and Solid Wastes Office
- San Francisco Water Quality Control Board

Universities: All institutions performing research on water quality management and/or remote sensing as applied to oceanography.

### 1.14 Documentation/References

1. E. A. Pearson, P. N. Storrs, and R. E. Selleck, "A Comprehensive Study of the San Francisco Bay," University of California-Berkeley Report No. 67-5 on the California State Water Quality Control Board Standard Agreements 12-28 and 12-24, July 1970.
2. J. C. Arvesen and E. C. Weaver, "Rapid Assessment of Water Pollution by Remote Sensing of Chlorophyll Content," presented at the Joint Conference on Sensing of Environmental Pollutants, Palo Alto, Calif., November 1971.
3. J. C. Aukland, W. H. Conway, and N. K. Sanders, "Detection of Oil Slick Pollution on Water Surfaces with Microwave Radiometer Systems," Sixth International Symposium on Remote Sensing of Environment, Proceedings, University of Michigan, October 13-16, 1969, University Press, pp. 789-796, 1969.
4. P. E. Sherr, A. H. Glaser, and J. C. Barnes, "World-Wide Cloud Cover Distributions for Use in Computer Simulations," Allied Research Associates, Inc., Report on Contract No. NAS8-21040, June 1968.
5. D. S. McCulloch, D. H. Peterson, P. R. Carlson, and T. J. Conomos, "A Preliminary Study of the Effects of Water Circulation in the San Francisco Bay Estuary," Geological Survey Circular No. 637-A, B, 1970.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Time of maximum power plant discharge: TBD

Time of minimum cloud cover (see 1.5): TBD

### 2.2 Frequency of Measurement/Observation

Daily to several times/day (see 1.5).

### 2.3 Total Time Span of Measurement/Observation

For a near polar 100 n. mi. orbit:

Nadir Viewing	12 seconds/pass
45° Pointing (Fore and Aft)	62 seconds/pass

### 2.4 Solar Elevation Angles

TBD. This is a function of time of year, time of day, and the desirability of sun glitter.

### 2.5 Cloudiness

Table 2 seems to suggest that the mission can be flown at any time during the year, but the local time at Bay crossing should be late morning.

Table 2. Cloud Cover

Seasonal Change in Cloud Amount	Mean Monthly (Jun - Aug)	Cloud Amount % (Dec - Mar)	Diurnal Variation	Time of Max. Cloud Amount
Small	50	50	Large	Early Morning

### 2.6 Ground Coverage

The field of view (at 100 n. mi. altitude) required to completely cover the Bay area in one near polar swath is ~28 degrees (100 nmi. swath width). It would be desirable to cover the entire West Coast of the United States with this swath width.

## 2.7 and 2.8 Resolution and Accuracy Requirements

Parameters of Interest	Spatial Resolution (Meters)	Spectral Resolution (Micrometers)	Accuracy		Amplitude
			Spatial (Meters)	Spectral (Micrometers)	
Floatables (e. g. oil slicks)	30	0.01	50	TBD	0.002 NE $\Delta\rho$
Transparency (turbidity)	30	0.01	50	TBD	0.002 NE $\Delta\rho$
Temperature (sea surface)	30	-	50	-	0.5 deg. C
Sea State	30	-	50	-	0.5 deg. C
Phytoplankton (chlorophyll)	30	0.015	50	.0025	0.002 NE $\Delta\rho$
Salinity	30	-	100		1 - 2 ‰

## 2.9 Shuttle Instrumentation/Equipment Requirements

### a) Primary Instruments

- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
- High Resolution Multispectral Camera System  
(70 mm film)  
Six cameras (four B&W, color, and false color)
- Wideband Synthetic Aperture Radar (WBSAR)  
(Medium Coverage, High Resolution Mode)
- Laser Altimeter/Scatterometer
- Visible Imaging Spectrometer
- IR Multispectral Mechanical Scanner  
(Ocean Surface Temperature Measurement)
- High Resolution Visible Imaging Spectrometer
- High Resolution IR Multispectral Mechanical Scanner  
(Ocean Surface Temperature Measurement)

- b) Correlative Support
  - Pointable Identification Camera
  - Data Collection System
- c) Support Equipment
  - Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Display (e.g., oscilloscopes)
  - Tape Recorders
  - On-board Data Processing Equipment.

## SUMMARY EVALUATION

### O2. SEA ICE MAPPING

Mapping and monitoring the extent of the polar ice caps can be used to estimate their heat sink capacity and their effect on global temperature changes, thus providing a basis for long-range weather forecasting. This information would also be useful in predicting ice boundaries for shipping in the high North and South latitudes.

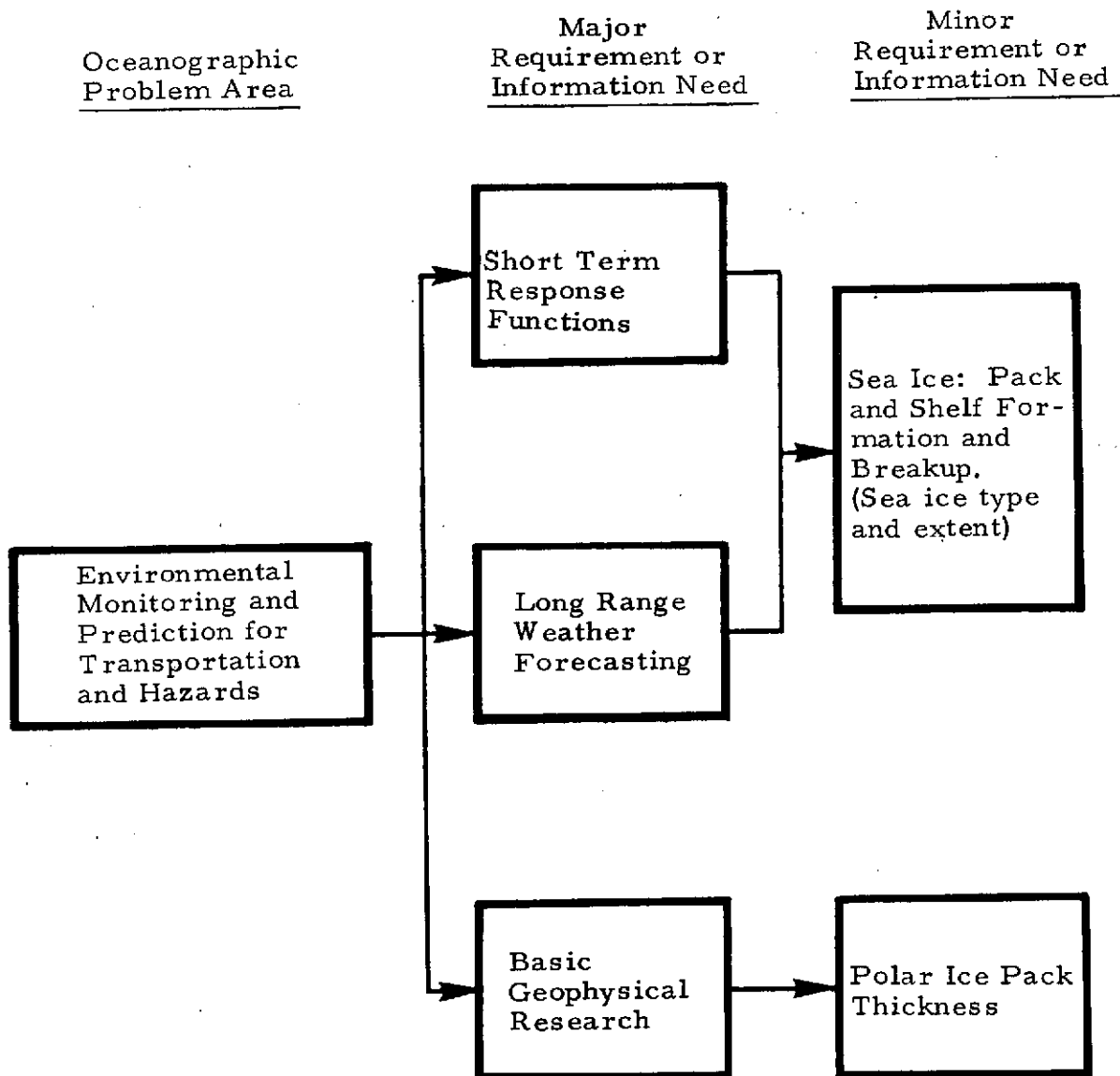
A multi-spectral complement of sensors on the Shuttle would map sea and glacial ice and investigate areas of interest. This experiment is a precursor to a fully developed operational system that would be applied on a coordinated multi-level multi-national basis.

The Shuttle (MEO) rating of this experiment is Level 1.

## O2. SEA ICE MAPPING

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas



#### 1.2 Experiment Objectives

- To measure the horizontal and to some extent the vertical dimension of sea and glacial ice as well as their distribution
- Determine ice type.

### 1.3 Experiment Background

Most sea ice observations are presently being made from ships and aircraft. These observations are restricted to areas which are easily accessible and are often hindered or prevented by fog, severe weather, or darkness. New techniques are needed to acquire observations over broad areas on an all-weather basis.

NAVOCEANO, through its sea ice reconnaissance program provides information for ship routing forecasts and scientific observations requiring the areal and seasonal distribution of sea ice. The reconnaissance includes observations on: ice concentrations, stage of ice development (related to thickness), water openings, ice forms, topography or roughness, ice boundaries, snow cover, and stage of melt and ice age (based on color).

Remote sensing and interpretation techniques are now being developed with the aid of sea ice reconnaissance. The basic remote sensing systems presently available are: photography in the visible and photographic IR portions of the spectrum, 0.4 to 0.9  $\mu$ ; infrared sensors, 1 to 40  $\mu$  (best window is the 8 - 14  $\mu$  band); and the microwave and radar sensors, 1 mm to 1 meter.

### 1.4 Proposed Technical Approach

To acquire polar ice data, the Shuttle would be placed in a near-polar orbit at an altitude of ~150 nmi. Because of Shuttle's short orbital lifetime, it appears unlikely that major dynamic events in the sea ice will be observed on a single mission. For this reason a five day coverage frequency will be used; a swath width of 100 nmi. will then give complete global coverage of the areas of interest provided the inclination is close to 90 degrees ( $\pm 4$  degrees). Sea ice dynamics can be obtained if the experiment is flown on several missions. Two good launch date candidates are the summer and winter equinoxes when the sun is at its highest latitude. At each of these dates, one pole will be in mid-winter while the other is in mid-summer.

Correlative support in the form of aircraft and ground stations would be desirable but not mandatory. They could supply information on regional cloud cover which would be useful in discriminating between clouds and ice.

The experiment would be conducted on two levels. One set of instruments would map sea ice on a continuous basis and would be completely

automated. A second set of instruments would be slaved to the tracking telescope and the investigator will track specific regions of interest (e.g., fractures) at high resolution. Viewing could then be done over many aspect angles and for longer periods of time.

The experimental approach will be as follows: In clear weather, the boundaries, texture, and albedo of snow and ice fields will be determined using black and white and color photography, and surface roughness can be determined using laser altimetry/scatterometry. Thermal infrared imagery will be used to determine thermal patterns of the surface during either daytime or nighttime conditions. Under cloud cover, synthetic aperture radar will be used to obtain imagery of sea ice, and passive microwave radiometry will obtain measurements of surface temperature.

To examine specific areas of interest, a gimballed tracking telescope will be used for both visual sighting and photographic recording. A photopolarimeter, slaved to the tracking telescope, will measure the degree of polarization of light reflected from the surface of the ice, indicative of surface roughness. A pointable microwave radiometer/scatterometer will obtain measurement of the radiometric temperature of the surface, using both horizontal and vertical polarization.

In this experiment the emphasis is upon high resolution, particularly with the microwave instruments. In contrast to the 13.8 - 14 GHz frequency of the S 193 microwave radiometer/scatterometer and the 1.4 GHz frequency of the S 194 L-band radiometer of Skylab, the high resolution requirement dictates the use of much higher frequencies for the Shuttle radiometer/scatterometers. By the use of the atmospheric window at approximately 37 GHz, discrimination of the type of sea ice can be determined with an order of magnitude better resolution than that achieved by the Skylab microwave radiometer/scatterometer. Through the use of additional frequencies (at approximately 5, 10.7, 18, and 21.5 GHz) and dual polarization, the effects of atmospheric water vapor, clouds, and precipitation can be determined.



### 1.5 Relevancy of Experiment

Mapping and monitoring the extent of the polar ice caps can be used to estimate their heat sink capability and their effect on global temperature changes. This will provide a basis for long-range weather forecasting and would be immediately useful in predicting ice boundaries for shipping in the high north and south latitudes.

The data acquired in this experiment will also supply information on sea ice type and distribution. This information will increase our understanding of sea ice dynamics.

This experiment is a precursor to a fully developed operational system that can be employed on a coordinated multi-level multi-national program to effectively monitor sea ice extent and effect on a global scale.

### 1.6 Role of Man

#### a) Experiment Activities

- Observe random targets of opportunity such as leads.
- Perform near real-time data analysis.

#### b) Instrumentation

- Detection and location of targets of interest with the tracking telescope
- Point and monitor instruments slaved to the telescope.

### 1.7 Impact of Experiment on Shuttle Sortie Mission

From an operational standpoint, the crew will be primarily involved with the gimballed sensor subsystem. Their activities will include the location of cloud free areas, selection and use of proper sensors and, when appropriate, the coordination of airborne activities. This requires precision pointing and tracking which will be done manually and at times by a programmed computer. To analyze the data on a near real-time basis, the crew will need onboard display equipment (CRTs) with the capability of producing false color images. Tape recorders will also be used for verbal descriptions.

The mapping subsystem will be fixed for nadir viewing, whereas the gimballed subsystem allows the investigator to freely point the instruments. Since both subsystems acquire high resolution data, storage may be a problem and ground stations may have to be heavily relied upon.

The observation frequency of instruments operating in the visible spectrum will be considerably less than the coverage frequency due to cloud cover in the polar regions.

#### 1.8 Supporting Research and Technology Required

- Develop onboard data storage and analysis systems to handle both sensor subsystems.

#### 1.9 Targets

- 1) Primary: Polar ice caps and high latitude sea ice
- 2) Secondary: River and lake ice.

#### 1.10 Truth Sites

Weather observation stations and weather ships in the high latitudes.

#### 1.11 Orbital Parameters

	<u>Desirable</u>	<u>Acceptable</u>
Alt.	100-150 nmi	150-250 nmi
Inc.	80°-90°	70°-90°

#### 1.12 Data Required by the Investigator

The data needs of the investigator aboard the Shuttle are as follows:

- High resolution monitoring of the area of interest and pointing of the gimballed instruments
- False color imagery
- Oscilloscope display of isolines associated with various data needs (e. g. , sea surface temperature)
- Tape recorder for verbal descriptions
- Instantaneous location of any area the investigator locates with his high resolution monitoring device. This data can then be placed in a computer and used for general pointing in the next acceptable pass.

### 1.13 Principal Users

#### Organizations:

- NOAA
  - Environmental Research Laboratories
  - Environmental Data Service
  - National Ocean Survey
- Department of Transportation
  - International Ice Patrol
- NASA
  - Spaceborne and Aircraft Oceanic Research
- U.S. Navy

#### Universities:

All institutions performing research on climatology.

### 1.14 Documentation/References

1. J. H. McLerran, "Remote Sensing and Interpretation of Sea-Ice Features," Oceans from Space, Editors, P. C. Badgley, L. Miloy, and L. Childs, Houston, Texas, Gulf Publishing Company, pp 159 - 170, 1969.
2. J. C. Barnes, D. T. Chang, and J. H. Willand, "Satellite Infrared Observation of Arctic Sea Ice," presented at the AIAA Earth Resources Observations and Information Systems Meeting, Annapolis, Maryland, March 2 - 4, 1970.
3. R. K. Moore and D. S. Simonett, "Potential Research and Earth Resource Studies with Orbiting Radars: Results of Recent Studies," Presented at the 4th Annual AIAA Meeting and Technical Display, Anaheim, California, October 23 - 27, 1967.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

February-March and August-September.

### 2.2 Frequency of Measurement/Observation

Once every five days (see 1.4).

### 2.3 Total Time Span of Measurement/Observation

Mapping Subsystem: At  $h = 100$  n. mi., 4.1 n. mi. is covered every second.

Gimballed Subsystem: With a 45 degree fore and aft pointing capability at  $h = 100$  n. mi. an object could be monitored for ~50 seconds.

### 2.4 Solar Elevation Angles (TBD)

### 2.5 Cloudiness

Consideration must be given to launch date and phasing of the orbit plane.

### 2.6 Ground Coverage

For a five day repeating orbit with an inclination close to 90 degrees, a swath width of approximately 100 n. mi. will cover the poles.

### 2.7 Resolution

50 - 100 meters.

### 2.8 Accuracy/Precision

1 km

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film

- Wideband Synthetic Aperture Radar (WBSAR)  
(Wide Coverage, Low Resolution Mode)
  - Laser Altimeter/Scatterometer
  - IR Multispectral Mechanical Scanner  
(Ocean Surface Temperature Measurement)
  - Visible Radiation Polarimeter (VRP)
  - Passive Multichannel Microwave Radiometer (PMMR)
  - Microwave Radiometer/Scatterometer
- b) Correlative Support
- Pointable Identification Camera
  - Data Collection System
- c) Support Equipment
- Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Display
  - Tape Recorders
  - Onboard Data Processing Equipment

## SUMMARY EVALUATION

### O3. PLANKTON PROFILING AND COASTAL BATHYMETRY MEASUREMENTS

The worldwide distribution of phytoplankton is extremely important in the management of the fisheries resource. Phytoplankton are the pasturage of the sea; the higher trophic levels of the food chain feed on phytoplankton. This experiment will demonstrate the feasibility of using a spaceborne system to measure the horizontal and to some extent the vertical distribution of phytoplankton.

SATS and EOS spacecraft will probably measure the horizontal distribution of chlorophyll (which is related to the horizontal distribution of phytoplankton). In a low inclination orbit, the Shuttle will monitor both the horizontal and vertical distribution of phytoplankton many times during the day. This experiment will test the feasibility of the proposed instrumentation and study the diurnal variation in the distribution of phytoplankton. The proposed instrumentation requires the participation of man in an operational mode and an analytical mode.

The Shuttle (MEO) rating of this experiment is Level 1.

### O3. PLANKTON PROFILING AND COASTAL BATHYMETRY MEASUREMENTS

#### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

##### 1.1 Associated Problem Areas

Coastal zone alteration and distribution of living marine resources.

##### 1.2 Experiment Objective(s)

Primary: Demonstrate the ability of a spaceborne system to determine horizontal and to some extent the vertical distribution of plankton in the world's oceans.

Secondary: Obtain coastal bathymetry measurements using multiband photography.

##### 1.3 Experiment Background

SATS and EOS spacecraft will probably carry sensors which will be used to measure and map the horizontal distribution of near-surface chlorophyll over large ocean areas.

As a result of the color photographs taken during the Gemini and Apollo missions, it was shown that ocean color is closely related to bottom topography. By mapping spectral contours in the areas of interest, a coastal bathymetric map could be constructed.

##### 1.4 Proposed Technical Approach

Measurements of spectral radiance will be made over pre-selected areas by means of a scanning spectrometer (such as those used in SATS or EOS) operating in the spectral range from 400 to 700 nanometers (nm.). In addition, measurements will be made of the vertical plankton profile<sup>1</sup> at specific points within the above areas by means of a new sensor to be developed. This sensor will consist of a very high power, pulsed laser, and a gated, filtered photomultiplier which will receive reflected laser radiation from various depths beneath the ocean surface.

The laser will have the following characteristics:

- It will have a beam divergence of the order of 0.1 mrad.
- Its peak power will be of the order of 1 megawatt (average power will be much less)
- Its emission wavelength will be modified by temperature control or other means to correspond with the wavelength of a suitably strong Fraunhofer line in the solar spectrum between 370 nm. and 600 nm. to minimize solar background interference.

The combination of sufficiently narrow beam divergence, high power, and low solar background should result in sufficient sensitivity to detect backscattered light from 200 n. mi. At the same time, short pulse durations will ensure ground safety, accuracy in depth profiling, and reasonably low average power. The sensor may be used day or night, but will be more sensitive at night.

The data will be interpreted on the basis of return time of the reflected light, longer times representing greater water depth penetration. The pulse length must be short relative to the time required for light to travel through a few meters of surface water. The sea surface can be recognized by the strong Fresnel reflection from the surface and used as a datum to determine the depth of the return from other pulses.

As the main purpose of the experiment is to determine the accuracy of the technique in making the required profiling measurements, the choice of specific targets is relatively unimportant, as long as good surface truth data is available at areas containing representative phyto-plankton distributions.

To obtain coastal bathymetry measurements in clear water areas, the orbit should be phased to cover as many coastlines as possible. In terms of the plankton distribution, many coastal areas exhibit high primary production and, as a result, there would be many suitable targets for profiling. In all probability, one or two target areas no more than 100 miles long would suffice for the entire range of distributions. The orbit should be chosen at low altitude and to give sufficient passes over the areas of interest to ensure that at least some cloud-free observations are obtained. Time of observation is unimportant but should include both day and night observations.



The participation of a scientist is essential to the operation of the experiment. As the target area is approached, he will calibrate the instrument by varying the timing of the detector gate until he has located the ocean surface. He will then activate the instrument as the target enters the field of view. At this point, the detector gate will automatically range through a series of time intervals representing various depths, beginning at the time represented by the ocean surface determined during calibration.

Off-nadir pointing of the laser must be accomplished with an accuracy of approximately 1 mrad and boresighting between laser and detector must be within approximately 0.01 mrad. Initial pointing of the equipment will be performed by the scientist with the aid of a high resolution telescope. The multiband photographic system, on the other hand, will be nadir viewing.

Surface truth will be obtained by ships. Surface measurements will consist of vertical plankton profiles at 0.5 mile spacing within an area about two miles on the side, with several such areas spaced at intervals along a path beneath the spacecraft and extending several miles. In addition, a complete set of observations on the atmosphere will be made over the test area (radiosondes, high altitude aircraft, etc.).

#### 1.5 Relevancy of Experiment

- Worldwide distribution of phytoplankton, pollution, and ocean upwellings
- Bottom topography maps for coastal areas.

#### 1.6 Role of Man

- Calibration of instrument before each data pass.
- Target acquisition
- Preliminary evaluation of data.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

The experiment is Shuttle-unique and requires the participation of man. Orbit parameters are of little importance, except for altitude and phasing and, although man's participation is essential, it should consume relatively little time.

### 1.8 Supporting Research and Technology Required

- Laser system sensitivity analysis
- Laser system development
- Detector and control logic development.

### 1.9 Targets

As described in Section 1.5, a variety of coastlines (e.g., coastlines of high productivity) should be covered at a time when the probability of cloud cover is minimal.

### 1.10 Truth Sites

Ships located in target areas.

### 1.11 Orbital Parameters

	Desirable	Acceptable
Altitude	100 - 150 n. mi.	150 - 250 n. mi.
Inclination -	0 - 10°	10° - 25°

Eccentricity - Zero

### 1.12 Data Required by Investigator

A small signal processor will be required to process laser pulse height and display it digitally in real time on a CRT so that the scientist may calibrate the instrument immediately before crossing the target area. The output will also be stored on magnetic tape. During the target pass the data will be stored on tape in digital form and will be inspected on the CRT later by the scientist. This inspection will only indicate if data was actually received, but will tell him little about the quality of the data, which will be determined by later analysis. He should inspect the data sometime before 30 minutes before his next target pass begins, so that he can make adjustments if necessary.

### 1.13 Principal Users

- Scientists involved in biological oceanography.
- Engineers interested in design of operational system.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Local spring or summer of major target areas.

### 2.2 Frequency of Measurement/Observation

Unimportant (see Section 1.5).

### 2.3 Total Time Span of Measurement/Observation

Less than 20 seconds for the plankton profiling.

### 2.4 Solar Elevation Angle

30 - 60 degrees.

### 2.5 Cloudiness

An observation cannot be made if clouds cover the target.

### 2.6 Ground Coverage

I. F. O. V. about 20 meters. Swath width the same.

### 2.7 Resolution

Same as I. F. O. V. horizontal. Vertical about 3 meters.

### 2.8 Accuracy/Precision

Of measurement -- as high as possible. Of measurement location -- about 20 meters.

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Multispectral Camera System  
24 x 24 cm (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
- Laser Altimeter/Scatterometer
- Visible Imaging Spectrometer

#### b) Correlative Support

- Pointable Identification Camera

c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Display
- Tape Recorders.

## SUMMARY EVALUATION

### O4. UPWELLING AREA MAPPING

The best fishing grounds are frequently located in areas of upwelling where the higher trophic levels of the food chain feed on phytoplankton. Many upwelling areas have been mapped fairly well, but only at specific times during the year. What is needed is a better documentation of the dynamics of seasonal upwelling as well as more information about those areas that have barely been explored (i. e., when do they start, how long do they persist, what is their intensity, etc.).

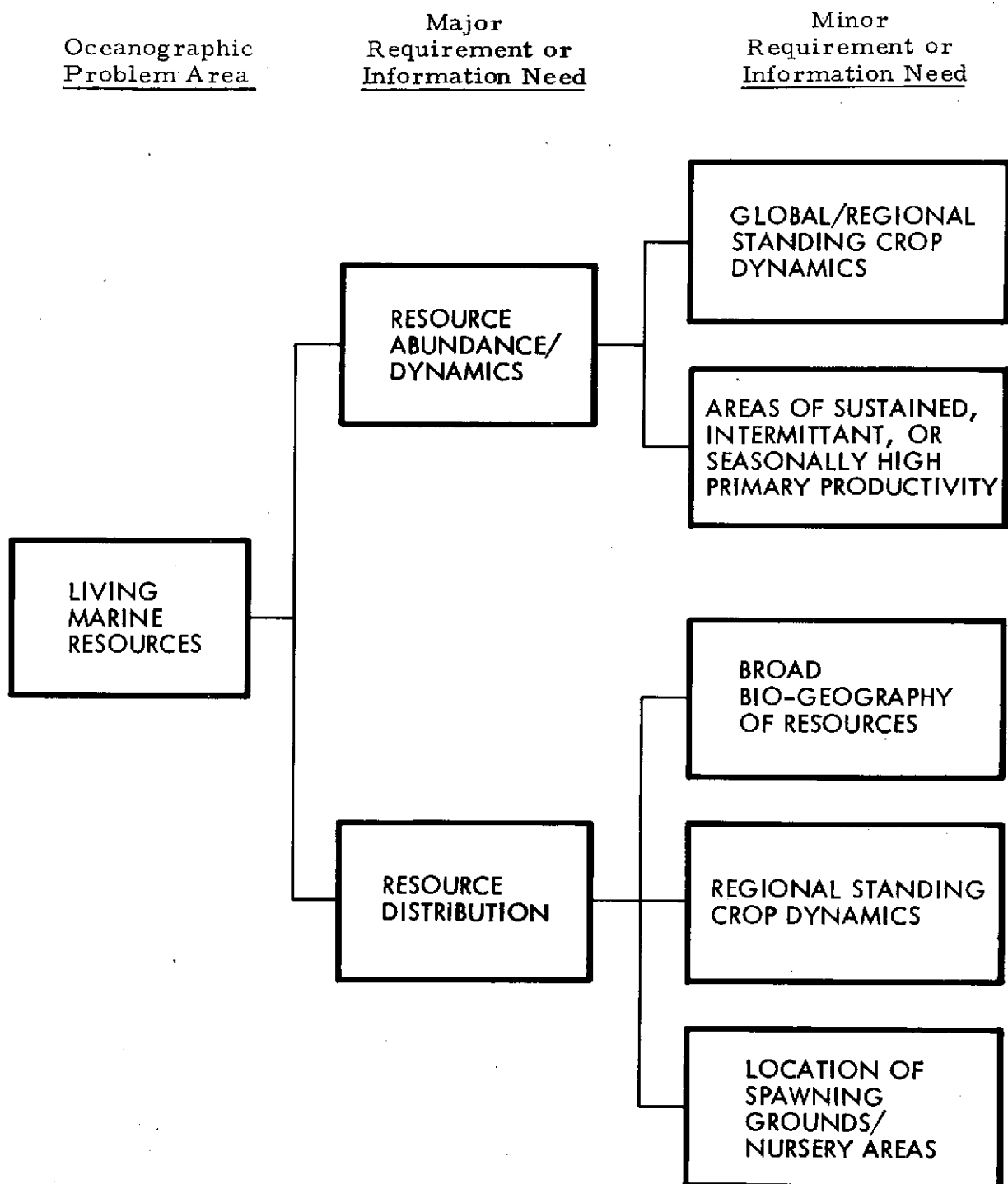
By performing this experiment on Shuttle in a low inclination orbit, areas of interest such as the Coast of Peru could be observed many times during the day and high resolution data could be obtained on upwelling dynamics. Eventually, the upwelling areas of the world would be monitored on a routine basis (but with a lower coverage frequency) from an unmanned spacecraft. With the aid of a gimbaled sensor subsystem, man would study areas of interest.

The Shuttle (MEO) rating of this experiment is Level 1.

#### O4. UPWELLING AREA MAPPING

##### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

##### 1.1 Associated Problem Areas



## 1.2 Experiment Objectives

- Test a method for locating the upwelling areas of the world.
- Map the spatial extent of the upwelling areas on a global basis and study their short term dynamics

## 1.3 Experiment Background

Upwelling is an ocean process in which vertical motion carries sub-surface water upward toward the surface. The cool upwelling water is nutrient rich and supports the phytoplankton in the euphotic zone.

Upwellings can be divided geographically into four categories: The east side of subtropical highs, downwind of islands and shoals, equatorial divergences and convergences, and high latitude divergences. Coastal upwellings are a result of Ekman transport of surface waters sustained by winds blowing parallel to the coast toward the equator, or are sustained where deep water replaces that carried away from coastlines by geostrophic currents. Oceanic upwellings include both divergences due to the vorticity of the wind stress around the subtropical anticyclone (applies to both the equatorial system and high latitudes) and geostrophic upwellings within the equatorial system itself.

## 1.4 Proposed Technical Approach

Allowing the El Niño effect\* to determine the year and date the mission would be flown, the Shuttle would be placed in a low altitude (~150 n. mi.), circle orbit. The orbit will be phased to maximize coverage of the coast of Peru, thereby observing El Niño conditions as often as possible. A "multi-look/day" cyclic frequency would be desirable.

Observations will be made in the visible and infrared portions of the electromagnetic spectrum. In the visible spectrum, real time measurements of chlorophyll concentration will be taken to indicate high con-

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\* El Niño - A warm ocean current setting south along the coast of Ecuador, so called because it generally develops just after Christmas. In exceptional years, concurrently with a southerly shift in the tropical rain belt, the current may extend along the coast of Peru to 12° South. When this occurs, plankton and fish are killed in the coastal waters and a phenomenon somewhat like the red tide of Florida and southern California results.

centrations of phytoplankton. Infrared measurements will detect the presence of cool upwelled water and provide a measure of the advective transport of upwelled water.

Ground truth would be accomplished by in-situ programs already gathering data on an operational basis as well as by in-situ programs set up specifically for the Shuttle mission (e. g., off the coast of Peru). A real-time communications link between the Shuttle and its correlative support would be used to coordinate future activities.

The scientist/astronaut's main function would be to evaluate CRT displays of lines of constant temperature and chlorophyll concentration and conduct precise off-nadir pointing at regions of interest with a set of high resolution instruments slaved to a tracking telescope. Another set of instruments of moderate resolution will map the upwelling areas on a regular basis.

#### 1.5 Relevancy of Experiment

The best fishing grounds are frequently located in areas of upwelling where the higher trophic levels feed on phytoplankton. Most upwelling areas throughout the world are mapped fairly well for specific times of the year (because of their seasonal occurrence), but global maps created from these discrete localized maps are very crude. What is needed is a better documentation of the dynamics of these seasonal upwellings as well as those that have not been investigated (i. e., when do they start, how long do they persist, what is their intensity, etc.). Once these areas are mapped on a global basis, it should be possible to better estimate the global areas of high fish catch potential and increase the efficiency of our fleet operations.

El Niño causes catastrophic destruction of plankton and fish life. Dead fish accumulating on the beach rot and lead to the formation of  $H_2S$  and, combined with sea fog, may even blacken the paint on ships. Sea birds die of starvation and the annual guano "crop" fails, leading to the impoverishment of agriculture. In the summers of El Niño years, heavy rains cause flooding and severe crop damage. Very little is known about what causes the El Niño effect and when it occurs. Understanding the



causes of El Niño as well as the dynamics associated with its presence will enhance our understanding of the ecosystem off the Peruvian coastline and supply additional information for disaster prediction.

#### 1.6 Role of Man

The primary role of man centers around his observation and analysis of areas of interest (e.g., El Niño). While one fixed set of instruments is mapping the upwelling areas on a regular basis, man will be tracking areas of interest with a gimballed set of instruments slaved to a tracking telescope. Evaluation of these areas will be accomplished through the use of CRTs.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

This experiment will impact the selection of an orbit for the mission in terms of the inclination and launch date parameters. A high inclination is required to map the upwelling areas on a global scale. To monitor El Niño the mission would have to be launched in certain years and, depending on the effect one is interested in, a specific time of year must be chosen (e.g., to observe the phenomenon in its early stages the mission would probably be launched at the end of December).

Installation and operation of the two sensor subsystems will impose structural and data handling requirements. The mapping subsystem will be fixed and nadir viewing whereas the gimballed subsystem will allow the scientist/astronaut to freely point the instruments. Since both systems acquire high resolution data, storage may be a problem.

#### 1.8 Supporting Research and Technology Required

- Develop onboard data storage and analysis systems to handle both sensor subsystems.

#### 1.9 Targets

##### General

- Global oceans

##### Specific

- Peruvian coastline.

#### 1.10 Truth Sites

- Areas with ongoing operational in-situ programs
- The Peruvian coastline will be instrumented to monitor El Niño.

#### 1.11 Orbital Parameters (Circular Orbit)

	Desirable	Acceptable
Altitude	100 - 150 n. mi.	150 - 250 n. mi.
Inclination	10° - 15°	20° - 30°

#### 1.12 Data Required by the Investigator

The data needs of the investigator aboard the Shuttle are as follows:

- Direct high resolution monitoring of areas of interest
- False color imagery
- CRT displays
- Shuttle ephemeris data.

Data needs of correlative support on the surface are:

- Appropriate location changes to optimize data taking
- Rise and set times of Shuttle over support area.

#### 1.13 Principal Users

##### Organizations

- NOAA – National Marine Fisheries Service
- EPA – Planning and Management, and Research and Monitoring.

##### Foreign Countries

- Major fishing nations of the world, especially Peru.

##### Universities

- All institutions performing research on bio-geography and current dynamics.

#### 1.14 Documentation/References

1. I. Hela and T. Laevastu, Fisheries Oceanography, London, England, Fishing News (Books) Ltd., 1970.
2. D. H. Cushing, "Upwelling and Fish Production," Fisheries Technical Paper No. 84, Paper presented at Food and Agriculture Organization of the U.N., June 1969, Rome, Italy, Food and Agriculture Organization, 1969.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

January - March (generally the beginning of El Niño)

### 2.2 Frequency of Measurement/Observation

Desirable: Three or More Times/Day

Acceptable: Once/Day

### 2.3 Total Time Span of Measurement/Observation

Mapping Subsystem: Continuous (visible instruments would be turned off on the dark side of the earth)

Tracking System: Depends on the phenomenon.

### 2.4 Solar Elevation Angles

30 - 90 degrees

### 2.5 Cloudiness

To minimize the occurrences of clouds the local time at the daylight node should be 10:00AM - 1:00PM.

### 2.6 Ground Coverage

The field of view should be large enough to obtain global coverage at the observation frequency required.

### 2.7/2.8 Resolution and Accuracy Requirements

	Mapping System	Tracking System
Spatial Resolution	2 Km	100 m
Spatial Accuracy	1 Km	100 m

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

##### Mapping Instruments

- Visible Imaging Spectrometer
- IR Multispectral Mechanical Scanner  
(Ocean Surface Temperature Measurement)

- High Resolution Visible Imaging Spectrometer
  - High Resolution IR Multispectral Mechanical Scanner  
(Ocean Surface Temperature Measurement)
- b) Correlative Support
- Pointable Identification Camera
- c) Support Equipment
- Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Displays
  - Tape Recorders.

## SUMMARY EVALUATION

### O5. OCEAN WIND AND WAVE/MEASUREMENTS

Ocean surface wind and wave information is a vital part of both long range weather prediction and transportation hazard prediction. Surface wind structure information would give the numerical modelers data on the air-sea interface at a microscopic scale which could be extrapolated to larger systems. Sea state and surface wind information would be used to develop hazard warning systems.

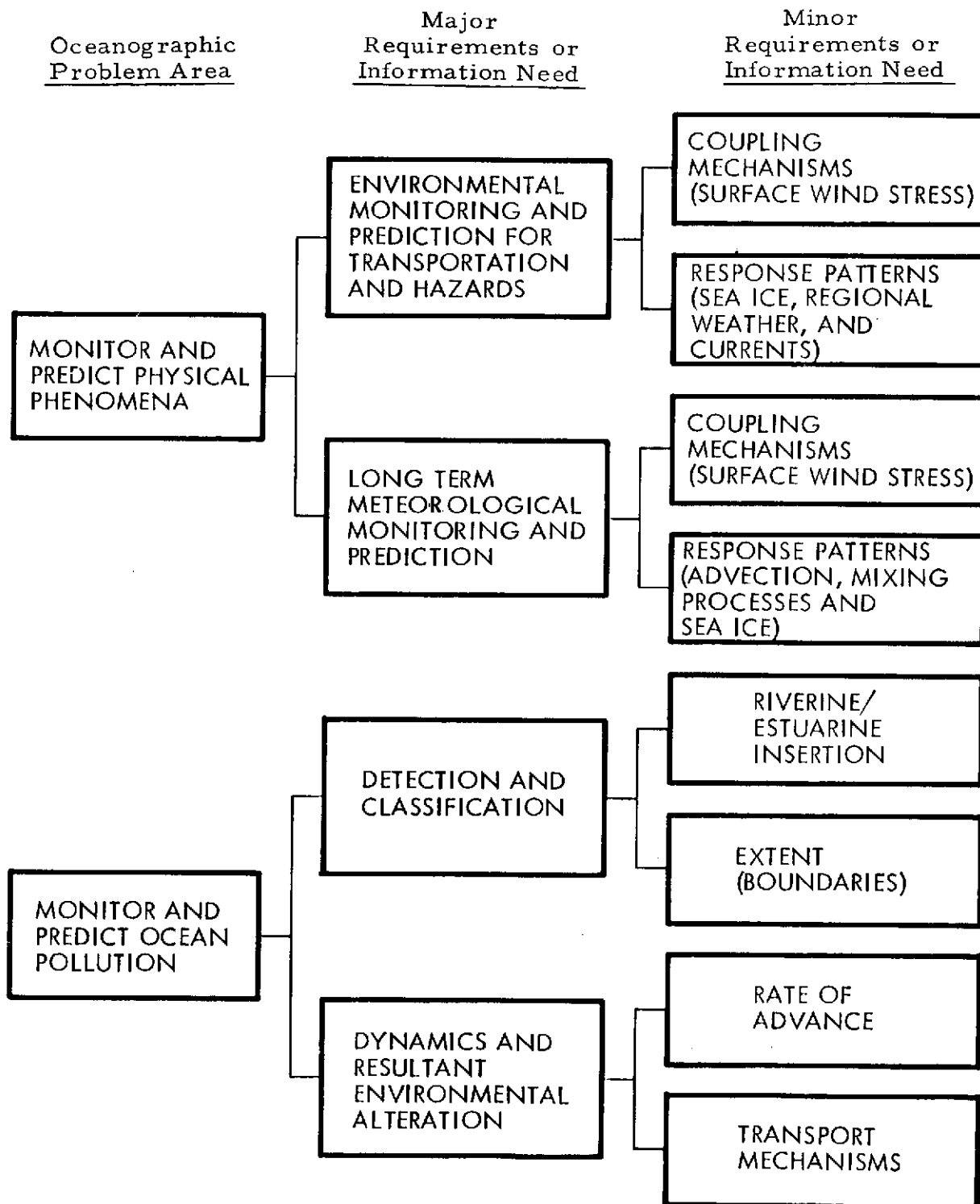
As a precursor to an operational system, the Shuttle will obtain high resolution data on sea surface conditions and, through observations of associated cloud systems by man and optical systems, this experiment will attempt to correlate sea state with cloud systems. The sensor subsystem will be more sophisticated than that of Skylab or any unmanned spacecraft slated for the same time period. Man will use a tracking telescope to investigate areas of interest such as islands or shoals and vary the selection instruments to obtain the most significant data.

The Shuttle (MEO) rating of this experiment is Level 1.

## O5. OCEAN WIND AND WAVE MEASUREMENTS

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas



## 1.2 Experiment Objectives

- Test a multisensor method of remotely measuring sea state, and surface wind speed and direction
- Analyze surface wind fields around islands and off coasts.

## 1.3 Experiment Background

Ocean surface wind information is a vital part of both short range weather prediction and wave prediction. Prediction of wave spectra involves knowledge of the surface wind field over large areas and long periods of time. Waves can propagate to large distances, and the effect of local winds is felt for many hours after the wind has died down. Hence, the numerical prediction techniques depend on the iterative solution of the appropriate equations over the period of a week. Numerical forecasting grids are presently very coarse (~120 km point spacing) because of computer capacity limitations and satellite instrument resolution constraints (tens of kilometers).

## 1.4 Proposed Technical Approach

A multisensor subsystem in the Shuttle at low earth altitudes (150 - 250 n. mi.) will monitor the appropriate data over a variety of areas at a high spatial resolution. The orbit will have a low inclination and will be phased to maximize coverage of coastlines and islands of interest. To monitor the short-term dynamics of the surface wind conditions, areas of interest should be observed from 1 to 3 times per day.

The sensor subsystem for this experiment in the Shuttle, like that of Skylab, includes a telescope and a microwave radiometer/scatterometer system. In addition, however, it includes a glitter camera, a high resolution camera system, a laser altimeter and a synthetic aperture radar. The entire subsystem, except for the calibrated synthetic aperture radar, will be automatically pointed to the surface area viewed through the telescope, so that correlated data will be obtained from targets of interest.

The Shuttle sensor subsystem will also provide much higher resolution microwave data than the 6 n. mi. provided by the Skylab S 193 radiometer/scatterometer and 60 n. mi. provided by S 194 L-band radiometer. This

resolution capability will permit monitoring the smaller-scale effects of surface winds and tidal wave action on coastlines and islands.

The synthetic aperture radar will permit surface mapping with resolution comparable to that of an optical instrument in the microwave region over large swath widths, after ground-based processing of the receiver output. Unlike an optical instrument, with the proper operating frequency, it will provide maps of the surface even through complete cloud cover. Visual and optical observations of the clouds thus can be correlated with sea state for possible early detection and tracking of associated cloud systems, line squalls, thunderstorms, tropical storms, etc. In addition to the maps showing sea state through correlation with radar backscattering coefficient, streaking in the maps may permit determination of wind direction.

In the absence of cloud cover, the radar maps may be compared with photographs of the glitter pattern, rad/scat data, and cloud height measurements using the laser altimeter, providing information which will help in the interpretation of the radar maps obtained through cloud cover.

With the aid of a tracking telescope, the observer will point the instruments (except the calibrated synthetic aperture radar) toward the glitter pattern and areas of interest such as islands and coastlines which do not fall along the subsatellite trace. The calibrated synthetic aperture radar will have a crosstrack pointing capability from  $\sim 10$  deg. to  $\sim 30$  deg. off nadir. This pointing will be coordinated with the telescope subsystem.

Ground truth will be accomplished by in-situ programs already gathering data on an operational basis.

#### 1.5 Relevancy of Experiment

The sensor subsystem previously described will obtain data on the following phenomena:

- Surface roughness
- Surface winds (speed/direction).



This data will indicate the physical condition of the sea surface and can be used to enhance numerical weather prediction models, it can be used as a precursor for an operational navigation system and the sensor payload can be evaluated as an advanced hazard warning system.

#### 1.6 Role of Man

Man's major role will be the observation and analysis of areas of interest (e. g., islands and coastlines). The glitter pattern will have to be carefully monitored when it is in the vicinity of areas of interest. This will also require pointing and tracking.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

Crew functions will include the location of cloud-free areas and the precision pointing of sensors using an observation and tracking telescope.

The mission orbit will be influenced by the experiment inclination and phasing requirements. A low inclination and the phasing which maximizes coverage of the areas of interest are needed to meet the objectives of this experiment.

#### 1.8 Supporting Research and Technology Required

- Radar antenna size, deployment, and control have to be studied
- Develop displays that will enhance man's analytical ability.

#### 1.9 Targets

##### General

- Global Oceans

##### Specific

- Coastlines, islands, and shoals.

#### 1.10 Truth Sites

- Areas with on-going operational in-situ programs.

#### 1.11 Orbital Parameters (Circular Orbit)

	<u>Desirable</u>	<u>Acceptable</u>
Altitude	100 - 150 n. mi.	150 - 250 n. mi.
Inclination	0 - 10 deg.	10 - 25 deg.

### 1.12 Data Required by the Investigator

Data requirements of the investigator aboard the Shuttle:

- Direct high resolution monitoring of areas of interest

Data needs of correlative support on the surface:

- Rise and set times of Shuttle over support area.

### 1.13 Principal Users

Organizations

- NOAA — Environmental Research Laboratories, National Weather Service, and the Environmental Data Service
- Department of Transportation — U. S. Coast Guard
- Department of Defense — U. S. Navy
- United Nations — World Data Center
- World Weather Watch
- World Oceanic Organization

Universities

- Institutions performing research on physical oceanography and numerical weather prediction.

### 1.14 References

1. R. K. Moore and W. J. Pierson, "Worldwide Oceanic Wind and Wave Predictions Using a Satellite Radar," Presented at the AIAA Earth Resources Observations and Information Systems Meeting, Annapolis, Maryland, March 2 - 4, 1970.
2. R. K. Moore and D. S. Simonette, "Potential Research and Earth Resources Studies with Orbiting Radars: Results of Recent Studies," Presented at AIAA 4th Annual Meeting and Technical Display, Anaheim, California, October 23-27, 1967.
3. A. E. Strong and I. S. Ruff, "Utilizing Satellite-Observed Solar Reflections from the Sea Surface As An Indicator of Surface Wind Speeds," Remote Sensing of the Environment 1:181-185, 1970.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

All Seasons

## 2.2 Frequency of Measurement/Observation

Desirable: 2 - 3 Times/Day

Acceptable: Once/Day

## 2.3 Total Time Span of Measurement/Observation

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## 2.4 Solar Elevation Angles

30 - 90 degrees

## 2.5 Cloudiness

To minimize the occurrences of clouds the local time at the daylight node should be 10:00AM - 1:00PM.

## 2.6 Ground Coverage

The field of view should be large enough to obtain adequate high resolution coverage of the areas of interest.

## 2.7/2.8 Resolution and Accuracy Requirements

	<u>Spatial Resolution</u>	<u>Accuracy</u>
Glitter measurement	350 m	350 m
Wave height measurement	25 cm	5 cm
Photographic recording	25 m	50 m
Radar imagery	30 m	30 m
Microwave radiometry and scatterometry	1500 m	1500 m

## 2.9 Shuttle Instrumentation/Equipment Requirements

### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Wideband Synthetic Aperture Radar (WBSAR)  
(Medium Coverage, High Resolution Mode)
- Laser Altimeter/Scatterometer
- Glitter Framing Camera
- Microwave Radiometer/Scatterometer.

b) Correlative Support

- Pointable Identification Camera
- Temperature and Humidity Profiles — Will Provide data relating to pertinent meteorological conditions in the atmosphere.

c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Displays
- Tape Recorders.

## SUMMARY EVALUATION

### O6. SUN GLITTER/MOON GLITTER MEASUREMENTS

Ocean surface wind and wave information is a vital part of both long range weather prediction and transportation hazard prediction. Surface wind structure information would give the numerical modelers data on the air-sea interface at a microscopic scale which could be extrapolated to larger systems. Sea state and surface wind information would be used to develop hazard warning systems.

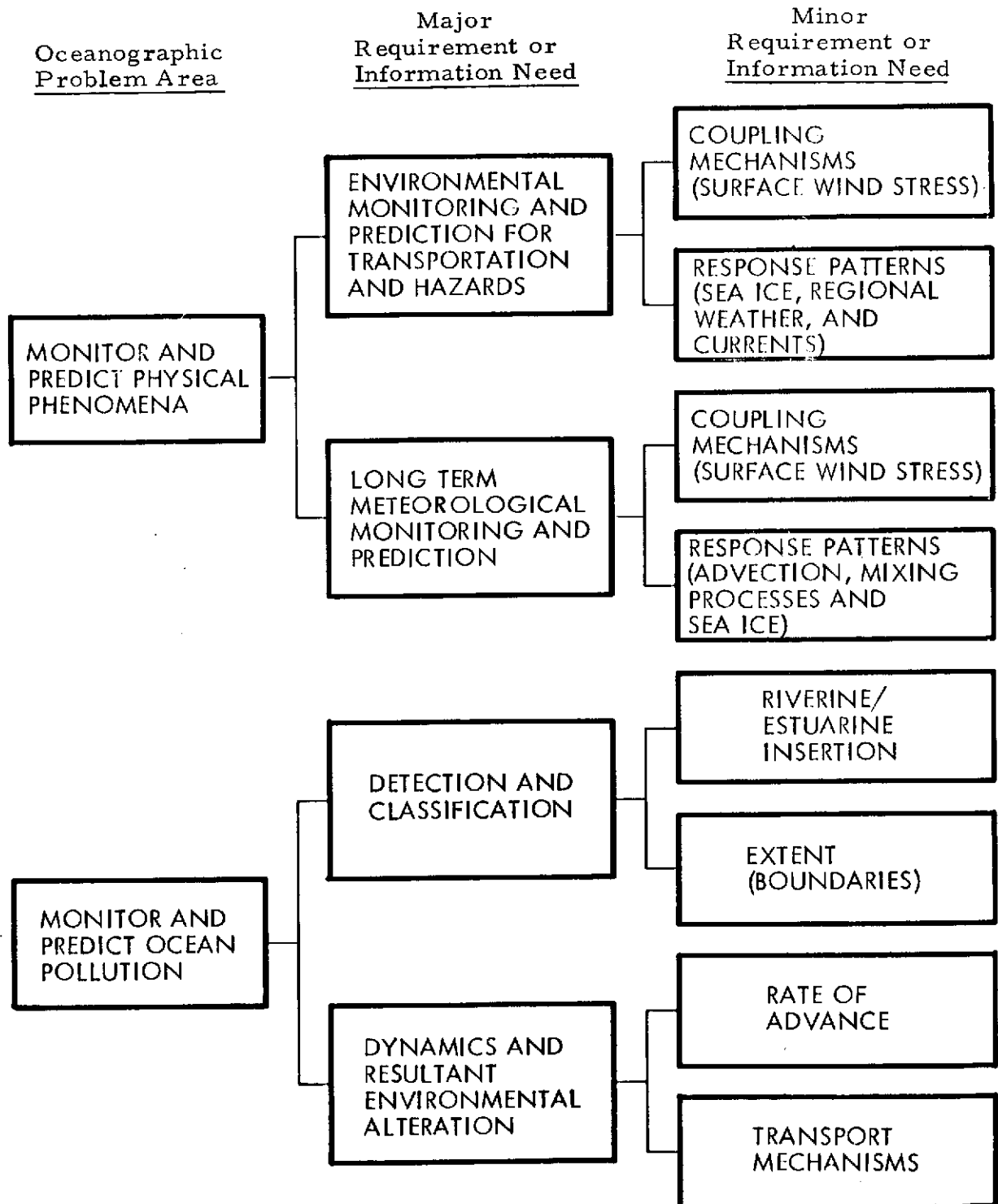
This Shuttle experiment would test the feasibility of using a visible system to monitor the sea surface condition on a day/night basis in a variety of areas (e.g., continent coastlines, islands, shoals, etc.). Man would train a gimballed sensor subsystem on areas of interest for further analysis (e.g., anomalous dark patches, streaks, etc.). The system would eventually be flown on an unmanned operational spacecraft system, like EOS.

The Shuttle (MEO) rating of this experiment is Level 1.

## O6. SUN GLITTER/MOON GLITTER MEASUREMENTS

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas



## 1.2 Experiment Objectives

- Test a visible method of measuring sea state and determining surface wind speed and direction
- Evaluate the utility of acquiring the above data at night using moon glitter.

## 1.3 Experiment Background

If the sea were absolutely calm, a single mirror-like reflection of the sun would be seen by a spacecraft. This single reflection would be seen at the horizontal specular point. In reality the sea is never calm; the sun's reflection is spread over the sea in a pattern of dancing highlights. Each highlight is a small water facet so positioned that the incoming solar ray is reflected toward the observer. The extent of the glitter pattern is limited by the maximum slope of the sea's surface. Using wave-slope statistics, which are governed by wind stress, the glitter pattern can be related to the sea state and wind speed. The shape of the pattern can be related to wind direction.

Photographs of sun glitter from aircraft (e. g., CV-990) and satellites (e. g., ATS III, ESSA, NIMBUS) have been analyzed since the mid-50s. As stated earlier, wind and sea conditions seem to affect the shape and brightness of the pattern. Anomalies or dark patches within the pattern have been related to upwelling areas and oil slicks.

## 1.4 Proposed Technical Approach

Since the moon's orbit plane is inclined to the ecliptic by five degrees and the plane of the earth's equator is inclined to the ecliptic by 23.5 degrees, the orbit inclination should be equal to the declination of the sun on a full moon day. A launch just before a full moon would take maximum advantage of the moon's reflecting capability in monitoring night glitter patterns. An inclination equal to the sun's declination during this period would minimize the off-nadir pointing required to monitor moon glitter. The orbital altitude should be between 100 and 250 n. mi. to acquire high resolution measurements with the primary and correlative instruments. To monitor the short-term dynamics of the surface wind conditions, observations over the same area should be taken every one to three times a day.

The primary instruments will be a glitter camera and a low light level photographic system. The glitter camera will operate in the

long wavelength portion of the visible spectrum to reduce the background effects of scattered sunlight, reflected skylight, and diffuse scattering from ocean surface layers, and to reduce measurement errors, the radiance at a contour away from the specular point will be measured. The photographic system will provide a picture of the overall scenes and will be used to analyze pattern anomalies. A microwave radiometer/scatterometer will be used as correlative support.

With the aid of a tracking telescope and a brightness filter, the scientist/astronaut will point the instruments at the glitter pattern. The pattern or lines of constant brightness will be displayed on a CRT for wind direction and pattern anomaly studies.

### 1.5 Relevancy of Experiment

The sensors previously described will obtain data on the following phenomena:

- Wind stress (surface roughness)
- Surface wind speed and direction
- Surface anomalies (e. g., oil slicks)

Wind stress on surface water is reflected in wave generation with a power spectral density equivalent to the energy coupled from the wind to the water. Wind velocity, fetch, and duration are statistically related to the average wave height. Direct measurement of sea state and directional wave spectrum is another method of obtaining wave information. Using both methods will furnish a better forecast of wave conditions.

Anomalous dark patches in glitter patterns generally indicate calm areas. These calm areas can be caused by a divergent surface wind field at the interface or oil slicks. If this surface anomaly were an oil slick, its extent and rate of advance could be monitored.

### 1.6 Role of Man

Measuring the brightness at a variety of radiance contours will be performed by an observer using a tracking telescope. For every measurement taken, the geographical location of the area being observed will be automatically recorded so that the pattern, in terms of radiance



contours, can be displayed on a CRT. This will enable the observer to detect anomalous patches that should be monitored with other sensors on subsequent passes. The observer will also locate cloud free areas.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

The mission orbit will be influenced in inclination and phasing requirements. To minimize the sensor pointing, an inclination equal to the sun's declination should be used. The phasing should correspond to a full moon period of the year to maximize the moon's reflecting capability.

A gimbaled platform slaved to a tracking telescope is needed to monitor specific locations within the glitter pattern.

#### 1.8 Supporting Research and Technology Required

- Develop displays to utilize man's analytical ability.

#### 1.9 Targets

General

- Global oceans

Specific

- Low latitude areas where oil slicks are likely to be present.

#### 1.10 Truth Sites

- Low latitude areas where oil slicks are likely to occur should be instrumented.

#### 1.11 Orbital Parameters (Circular Orbit)

	Desirable	Acceptable
Altitude	100 - 150 n. mi.	150 - 250 n. mi.
Inclination	Equal to sun's declination on launch date	

#### 1.12 Data Required by Investigator

Data requirements of the investigator aboard the Shuttle:

- Direct high resolution monitoring of areas of interest.

Data needs of correlative support on the surface:

- Rise and set times of Shuttle over support area.

### 1.13 Principal Users

#### Organizations

- NOAA – Environmental Research Laboratories,  
National Weather Service, and the  
Environmental Data Service
- Department of Transportation – U. S. Coast Guard
- Department of Defense – Navy
- United Nations – World Data Center
- World Weather Watch
- World Oceanic Organization

Universities: Institutions performing research on physical  
oceanography and numerical weather prediction.

### 1.14 References:

1. A. E. Strong and I. S. Ruff, "Utilizing Satellite-Observed Solar Reflections from the Sea Surface As An Indicator of Surface Wind Speeds," Remote Sensing of the Environment 1:181-185, 1970.
2. C. Cox and W. Munk, "Measurement of the Roughness of the Sea Surface from Photographs of the Sun's Glitter," Journal of the Optical Society of America 44:838-850, November 1954.
3. C. J. Bowley, J. R. Greaves, and S. L. Spiegel, "Sunlint Patterns: Unusual Dark Patches," Science 165:1360-1362, September 1969.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

All seasons; full moon conditions.

### 2.2 Frequency of Measurement/Observation

Desirable: 2 - 3 Times/Day

Acceptable: 1 Time/Day

### 2.3 Total Time Span of Measurement/Observation

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### 2.4 Solar Elevation Angle

See 1.4

### 2.5 Cloudiness

The launch should occur during occurrence of the full moon and when cloud-free areas are predicted over the ocean in the tropics.

### 2.6 Ground Coverage

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### 2.7/2.8 Resolution and Accuracy

	<u>Spatial Resolution</u>	<u>Accuracy</u>
Glitter pattern measurement	350 m	350 m
Microwave Radiometry and Scatterometry	1500 m	1500 m

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Glitter Framing Camera
- Microwave Radiometer/Scatterometer

#### b) Correlative Support

- Pointable Identification Camera

#### c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Displays
- Tape Recorders.

## SUMMARY EVALUATION

### O7. REMOTE CENSUS OF FISH SCHOOLS

A need exists to routinely monitor, assess, and predict the status of living marine resources as a basis for development of a prudential resource management strategy. In the late 1970s, Phase 3 of the National Marine Fisheries MARMAP Program will be assessing the pelagic stocks of the oceans. A basic aspect of this assessment will be the aircraft surveying of surface-schooling fish. Using a high resolution telescope and photographic system, the Shuttle observer will spot schools and direct aircraft to these areas for a "close look" count.

The Shuttle (MEO) rating of this experiment is Level 2.

## O7. REMOTE CENSUS OF FISH SCHOOLS

### OBJECTIVE

To measure the abundance and size of near surface fish schools in selected ocean regions.

### BACKGROUND AND RELEVANCY

A need exists to routinely monitor, assess, and predict the status of living marine resources as a basis for development of prudential resource management strategy. The MARMAP program of the National Marine Fisheries Service is designed to accomplish this objective. The first phase of the program, now being implemented, will address plankton-environmental relationships; the second phase will involve surveys of demersal fish stocks; the third phase will emphasize remote assessment of pelagic stocks. Although planning for Survey 3 is only in the formative stages, it appears likely that it will be implemented in the late 70s--possibly in 1976 as a preliminary operational capability program. A basic aspect of the survey will be remote assessment of surface-schooling fish, at least from aircraft. Two precursor projects are now in the planning stages for the Gulf of Mexico that will involve aircraft fish spotting and environmental data from ERTS-A and Skylab. This experiment, involving direct fish census from orbital altitudes, would seem a logical extension of these projects. Knowledge of number of fish schools near the surface at a given time over a large area, coupled with data on probability of a school being near the surface, would provide valuable pelagic stock assessment data.

### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

The primary advantages offered by the Shuttle mission for the purposes of this experiment are large payload capability, low orbit, and experimental flexibility--particularly the pointing capability of the experimenter. A large photographic telescope would be used over areas where atmospheric transparency is optimal. The experimenter would visually spot areas with schools, photograph them, and direct aircraft to the areas for "close look" counts of schools, estimates of school size, and identification of the schooling fish. Polarization and spectral filters would probably be used to enhance contrast.

## SUMMARY EVALUATION

### O8. SEDIMENT AND POLLUTION DIFFUSION

The estuaries and coastal margin waters of the ocean serve as a primary receptacle for most of man's liquid wastes, as well as much of the solid and atmospheric-borne wastes. The concentration of these wastes in narrow coastal regions is already severely stressing their ecosystems. By determining the distribution and rate of turbulent diffusion of sediment and pollution as a function of time, we can get a better understanding of water circulation.

The experiment would employ aircraft in the early stages, but they would soon be limited by their effective coverage ability. Because of the short duration and high resolution requirements of the experiment, the Shuttle would be the best carrier vehicle. Man would monitor and interpret the progress of the experiment.

The Shuttle (MEO) rating of this experiment is Level 2.

## 08. SEDIMENT AND POLLUTION DIFFUSION

### OBJECTIVE

To determine the distribution and rate of turbulent diffusion of sediment and pollution as a function of time after release from river estuaries and sewage outfalls.

### BACKGROUND AND RELEVANCY

The estuaries and coastal margin waters of the ocean serve as a primary receptacle for most of man's liquid wastes, as well as much of the solid and atmospheric-born wastes. The concentration of these wastes in narrow coastal regions is already severely stressing their ecosystems.

Because of the rapid spreading of cities and the accompanying building and soil disturbances, a great deal of soil shifting in water basins and drainage systems has occurred. This is causing extensive disturbance to fresh water streams and lakes as well as estuarine and salt water marsh habitats. This sediment causes physical and biological problems. When suspended, it reduces water clarity and sunlight penetration, thereby affecting the biota. As it settles to the bottom it buries and kills vegetation and alters the benthic biota. It also fills channels and harbors, requiring expensive remedial measures.

Turbid water is clearly visible from satellite altitudes. Mapping of ocean water clarity has been shown feasible by analyzing the 70 mm transparencies of the Gemini photographs.

Tracer dye tests have been conducted since the early 1950s to determine the detailed behavior of various water systems. Pacific Gas and Electric has used tracer dye to study industrial effluent and intake systems. Battelle-Northwest has studied the transport of conservative and non-conservative pollutants in surface water bodies using rhodamine-B dye and a multichannel optical mechanical scanner.

### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

Although we know much about problems caused by sediment, we need to know much more about how sediments, through their surface activity, interact with heavy metals and affect the general water chemistry. Remote sensing offers the most efficient means of examining the problem because broad areas need to be examined continually of an extended period of time.

The primary instruments for this experiment will be a Fraunhofer line discriminator and a multichannel optical mechanical scanner which will determine the concentration and distribution of a dye in the areas of interest. Several days prior to launch, large quantities of rhodamine-B dye will be released in the areas of interest. During the prelaunch period, aircraft with Fraunhofer line discriminators and multichannel optical mechanical scanners will monitor the dye. Once the dye covers an area beyond the effective coverage ability of the aircraft, similar measurements will be made by the Shuttle.

For correlative support an imaging spectrometer, a multispectral photographic system, and a correlation radiometer would also be flown.



## SUMMARY EVALUATION

### O9. EUTROPHICATION STUDY

In the coastal marine environment, in estuaries, and in lakes the level of nutrients is much higher than the open ocean, due partly to natural sources such as upwelling, wave and tidal action, etc., and partly due to man-made sources such as human waste, detergents and agricultural fertilizer. High resolution surveys of instrumented and non-instrumented areas of interest would provide valuable data which would lead to a reduction in eutrophication through effective resource management.

The Shuttle's short duration high-resolution monitoring capability makes it an excellent tool for resource management on a multi-level basis over many areas of the globe. Man would track and evaluate areas of interest.

The Shuttle (MEO) rating of this experiment is Level 2.

## O9. EUTROPHICATION STUDY

### OBJECTIVE

Assess the degree of eutrophication in several instrumented coastal regions (e. g., estuaries, bays, etc.).

### BACKGROUND AND RELEVANCY

The synthesis of organic matter from inorganic matter in the euphotic zone of the ocean is accomplished through photosynthesis and is commonly called primary production. The rate of photosynthesis is governed, in most instances, by the availability of light and inorganic nutrients, primarily nitrates and phosphates. These nutrients are inducted into the water bodies through either man-created or natural means. It is believed that phosphates and nitrates are most responsible for excessive growth of algae and wees, although vitamins, silicate, iron and trace metals also affect the growth of algae.

In the coastal marine environment, in estuaries, and in lakes the level of nutrients is much higher than the open ocean, due partly to natural sources such as upwelling, wave and tidal action, etc., and partly to man-made sources such as human waste, detergents and agricultural fertilizer.

The change in a water body in which the plant and animal life increase in abundance and complexity because of an increase in nutrients is called eutrophication. If this process gets out of hand, it can be catastrophic. One of the first effects of eutrophication is an exaggerated diurnal cycling of the oxygen content. During the day photosynthesis can supply enough oxygen to cause saturation, but at night the metabolic oxygen demand of the entire biomass can deplete the supply, causing the destruction of many desirable life forms. The decomposition of the organic matter will further deplete the oxygen supply. A second effect of eutrophication is the decrease in the depth of sunlight penetration resulting in continuing and progressive oxygen demand in the bottom waters.

Although some specific nutrient wastes can not be directly sensed from space, their presence may be inferred from the concentration of phytoplankton. Oxygen depletion may be detected through the presence of

dead organisms. Additionally, all photosynthetic processes occur in the presence of chlorophyll, the primary pigment of phytoplankton. Correlations have been found between chlorophyll concentration in surface waters, primary productivity, euphotic zone chlorophyll, euphotic zone depth, and sea surface temperature. Chlorophyll is thus an important indicator of basic biological processes. It should be pointed out that sometimes surface chlorophyll will show no correlations with water column productivity. Where the water column is well mixed, the correlation would be expected to hold.

#### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

The instrumentation in the areas of interest will obtain data on: biological oxygen demand, ammonia nitrogen, nitrate nitrogen, coliform bacteria, phytoplankton, and the vertical temperature profile.

The Shuttle-borne instruments will obtain information on: chlorophyll content, sea surface temperature, and ocean color. The sensor subsystem will include:

- Multispectral Camera System — Will be used to indicate the lack of oxygen (e.g., through the browning or algae)
- Chlorophyll Correlation Radiometer — Will provide real-time measurement of chlorophyll concentration
- Visible Imaging Spectrometer — Will provide an array of spectral signatures which can be read out on a CRT
- IR Imager/Radiometer — Will obtain the sea surface temperature.

During the mission, the astronaut/scientist will monitor coastal areas of interest using a tracking telescope to which the instruments are enslaved. On any given pass, CRT displays will allow the observer to determine which non-instrumented areas should be observed on subsequent passes.

## SUMMARY EVALUATION

### O10. STUDY OF CURRENT DYNAMICS

Advection is one of the most important factors causing local changes in environmental properties of the sea. Fish can be expected to respond directly to those environmental changes brought about by currents as well as to respond to the currents themselves. The atmosphere and ocean are closely related and the workings of their interaction help maintain the earth-atmosphere energy balance.

This Shuttle experiment would test the feasibility of using a multi-spectral sensor subsystem to map the location, areal extent, and vector of surface currents. This data would eventually be gathered on an operational basis by an unmanned spacecraft like EOS.

The Shuttle (MEO) rating of this experiment is Level 3.

## O10. STUDY OF CURRENT DYNAMICS

The location, areal extent, and vector of surface currents will be mapped at several opportune times during the year by obtaining data on sea surface temperature, displacement of surface objects, and ocean color. Since, on an operational basis, continuous global monitoring will be required, the proposed Shuttle sortie mission will be designed to test the feasibility of gathering the needed data using a multispectral complement of sensors. To obtain global data, the Shuttle should be placed in a near polar orbit.

## SUMMARY EVALUATION

### O11. LIGHT IN THE SEA

The signal received at a sensor above the earth's atmosphere is composed of four components: upwelling radiation, reflected direct beam radiation, reflected diffuse radiation, and the radiation due to atmospheric reflection and scattering. Because of the relatively small magnitude of the upwelling radiation signal, it is difficult to obtain. Severe accuracy and sensitivity requirements have to be placed on the total signal and the calibration of the instrument to obtain usable data. To better understand the total signal components, one should evaluate the effects of the optical properties of ocean water beneath the surface, the air-sea interface, and the atmospheric interference.

This experiment determines the attenuation in the air-sea column by monitoring a series of lights beneath the ocean's surface. If this experiment was ever flown it would be in an aircraft and the lights would probably be placed in an instrumented water tank.

The Shuttle (MEO) rating for this experiment is not selected.

## O11. LIGHT IN THE SEA

This experiment will determine the attenuation of upwelling radiation within the near surface water column and the air column. It will also evaluate the spread and intensity distribution of light sources as a function of the condition of the sea surface. This will be accomplished by monitoring a series of lights or reflectors placed beneath the ocean's surface with a low-light level, high-resolution imager, photography, and a microwave radiometer/scatterometer. It is expected that the shape and distribution of the intensity of each light (reflector) and of the matrix will bear a strong relationship to the sea state and provide a standard for those sensors designed to measure the state of the sea.

## SUMMARY EVALUATION

### O12. OIL SPILL IDENTIFICATION

Oil discharges into coastal and estuarine waters are known to be responsible for loss of wildlife and commercially valuable fish and mollusks as well as affecting recreational facilities and the aesthetics of our natural aquatic environment. The reflective and fluorescence properties of oil make it amenable to remote sensing techniques.

Automated spacecraft will eventually monitor the world's oceans for oil spills on an operational basis. Aircraft would probably be adequate to test the feasibility of using a laser to identify oil spills. In addition, there is some question as to the value of such an experiment on the Shuttle because of the pulse-receive time lag, the amount of power required and the large number of fluorescence wavelengths.

The Shuttle (MEO) rating of this experiment is, therefore, Not Selected.



## O12. OIL SPILL IDENTIFICATION

To test the feasibility of using a high-power pulsed nitrogen laser and a number of gated filtered photomultipliers for identifying oil spills from space on an operational basis, a controlled spill will be monitored from the Shuttle. The wavelength and strength of the fluorescence will be used to specifically identify the type of oil used. Very accurate pointing will be required (on the order of 1 mrad).

## SUMMARY EVALUATION

### O13. LASER STIMULATION OF BIOLUMINESCENCE

Using a laser to detect bioluminescence of planktonic organisms on a Shuttle mission is questionable for several reasons:

- 1) The pulse duration probably isn't long enough
- 2) There is an extremely high power requirement
- 3) There is a pulse-receive time lag
- 4) Bioluminescence covers a wide range of wavelengths.

Furthermore, the feasibility of such a technique probably should be tested in aircraft.

The Shuttle (MEO) rating of this experiment is Not Selected.

### O13. LASER STIMULATION OF BIOLUMINESCENCE

This experiment will determine the feasibility of using a very high-power, low dispersion, slow-scanning CW laser and a low-light level scanning detector to sense bioluminescence of planktonic organisms. Since plankton is the food of higher levels of the food chain, there would be a high probability of finding fish schools in the same vicinity. The location of fish schools would be transmitted to ships for confirmation by echo sounders.

### 3.2 METEOROLOGY (M) EXPERIMENTS

## SUMMARY EVALUATION

### M1. NOCTILUCENT CLOUD PATROL

Since the physical and chemical nature of noctilucent cloud particles is still not well understood, there remains much conjecture about their origin (i. e., whether it is terrestrial, extraterrestrial, or local), and their mode of formation. These questions are important in the meteorology of the upper atmosphere, in its photochemistry, in the vertical transport of water vapor and dust particles, and in the influx of micro-meteorites into the atmosphere.

This experiment will provide measurements and observations of intensity and polarization over a wider range of scattering angles than are possible from earth's surface. These will be important in settling the question of the existence of metallic or absorbing particles in the clouds. It would also provide answers relating to cloud occurrence in the Southern Hemisphere, the extent of the cloud formations, and information on their motion.

The proposed technique is particularly suited to a manned experiment as against automated photo-polarimetry, in that the observer would scan the twilight horizon and the subsatellite area in order to detect and identify noctilucent clouds (the detection would be accomplished visually).

This experiment is considered to be MEO Level 1 for Shuttle sortie missions.

## M1. NOCTILUCENT CLOUD PATROL

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas

Meteorology of the Upper Atmosphere, particularly its composition.

#### 1.2 Experiment Objectives

- Detect, identify and map noctilucent clouds in the mesosphere
- Study their morphology
- Determine the nature and composition of the cloud particles
- Determine whether the appearance of noctilucent clouds is always limited to high latitude summers.

#### 1.3 Experiment Background

Noctilucent clouds have only been observed when the atmosphere below them is dark, and then only rarely. Although they appear in both hemispheres, they have been seen almost exclusively during polar summers at about 82 km. Their rapid formation suggests condensation, and since temperatures in the polar summer at 80 km are lower than anywhere else in the atmosphere at any other time, condensation of water vapor is a popular (but not only) explanation. There remains much uncertainty about the composition of these clouds, how they are formed, the origin of the cloud particles, and why they seem to appear most frequently at certain latitudes and during certain months.

Until recently, the only way to study the nature, size, and amount of these upper atmospheric particles without actual sampling has been by the analysis of ground-based photometric, photographic and polarimetric observations. These are greatly influenced by single and multiple Rayleigh scattering and by the turbidity in the lower atmosphere. The difficulties can be overcome by balloon and rocket-borne photopolarimetry, which offers the added advantage of extending measurements to the ultraviolet. In this spectral region substantial deviations from the Rayleigh scattering law may be caused by very small particles which scatter light according to this law in the visible spectrum. During 1962 and 1964 a

cooperative Swedish-American experiment directly collected noctilucent cloud particles by means of sounding rockets,<sup>1</sup> but these experiments were inconclusive and did not corroborate each other.

The possibility of photometric detection of noctilucent clouds in the twilight zone as seen from outside the atmosphere from a polar-orbiting unmanned satellite was discussed by Deirmendjian<sup>2</sup> and by Rosenberg.<sup>3</sup> Witt<sup>4</sup> suggested that an investigation be made of their possible occurrence in the sunlit portion of the atmosphere, where illumination conditions preclude visual observation. Knowledge of their daytime distribution and their occurrence in polar regions would be essential to any theory about the mechanism of formation and maintenance of these clouds.

#### 1.4 Proposed Technical Approach

The proposed technique is particularly suited to a manned experiment as against automated photo-polarimetry, in that the observer would scan the twilight horizon and the subsatellite area in order to detect and identify noctilucent clouds. The detection would be accomplished visually. With a photometer sensitive to the entire visible spectrum, some information about the thickness and vertical extent of the clouds could be deduced. The nature of the particles would be investigated using several filters (e. g., transmitting blue and red light) with several polarizations for each. Over the sunlit portion of the atmosphere, the technique would use spectral regions where the illumination of the lower-lying atmosphere is strongly reduced by selective absorption, and where the presence of solid particles is expected to cause polarization anomalies or an increase in the atmospheric albedo. Such regions are, for example, the Hartley band of ozone at 2500 to 2700Å and the Schumann Runge bands of molecular oxygen (~1950Å).

Investigation of the nature and lifetime of rocket exhausts, such as are reported to have been seen several hundred miles from launch sites, would also be valuable providing as they would a better estimate of the atmospheric diffusion coefficient at various altitudes.

#### 1.5 Relevancy of Experiment

Since the physical and chemical nature of noctilucent cloud particles is still not well understood, there remains much conjecture about their

origin (i. e., whether it is terrestrial, extraterrestrial, or local), and their mode of formation. These questions are important in the meteorology of the upper atmosphere, in its photochemistry, in the vertical transport of water vapor and dust particles, and in the influx of micrometeorites into the atmosphere.

Additionally, this experiment would provide measurements and observations of intensity and polarization over a wider range of scattering angles than are possible from the earth's surface. These will be important in settling the question of the existence of metallic or absorbing particles in the clouds.

#### 1.6 Role of Man

The primary role for man would be to scan the twilight horizon as well as the subsatellite area to detect and identify noctilucent clouds. This could be done visually and with the aid of simple filters to determine whether a luminous layer is emitting or scattering. The observer would tape verbal descriptions of the gross features of morphology and brightness and record these by simple photography. In addition, he would initiate automated photo-polarimetric measurements whenever noctilucent clouds are identified.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

A high inclination orbit will be required as will observations during Northern Hemisphere summer months. The latter requirement may be relaxed in later flights as evidence is sought for the appearance of noctilucent clouds at other times of year. With sensors fixed to the nadir-oriented part of the satellite, observations in the twilight zone as seen from outside the atmosphere can be made without astronaut participation.

#### 1.8 Supporting Research and Technology Required

Present technology sufficient to conduct this experiment.

#### 1.9 Targets

Twilight horizon and subsatellite areas will be visually scanned as will the sunlit portion of the atmosphere for the detection of luminous clouds in the mesosphere.



#### 1.10 Truth Sites

None

#### 1.11 Orbital Parameters

- 1) Altitude: Less than 300 n. mi. acceptable.
- 2) Inclination: Polar preferred; 65 degrees acceptable
- 3) Eccentricity: Low.

#### 1.12 Data Required by Investigator

Photometric, polarimetric, and photographic records of noctilucent cloud observations; tape-recorded visual observations and descriptions by observer; tape recorded Shuttle position, altitude and attitude data.

#### 1.13 Principal Users

Atmospheric scientists concerned with upper atmosphere dynamics, structure and composition.

#### 1.14 Documentation/References

1. C. L. Hemenway, R. K. Soberman, and G. Witt, "Investigations of Noctilucent Cloud Particles," Tellus, Vol. 16(1), pp 84-109, 1964.
2. D. Deirmendjian, "Detection of Mesospheric Clouds from a Satellite," in Proc. of the First International Symposium on Rocket and Satellite Meteorology, North-Holland Publication Co., Amsterdam, pp 406-411, 1963.
3. G. V. Rosenberg, "On the Observability of Noctilucent Clouds and Nacreous Clouds from a Spacecraft," English edition of Izvestia AN SSSR, Atmospheric and Oceanic Physics, Vol. 2(1), pp 21-27, 1965.
4. G. Witt, "Optical Characteristics of Mesospheric Aerosol Distributions in Relation to Noctilucent Clouds," Tellus, Vol. 20(1), pp 98-113, 1968.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION REQUIREMENTS

### 2.1 Time of Year/Season

Initially Northern Hemisphere summers; subsequently, detectability required in all seasons.

### 2.2 Frequency of Measurement/Observation

Whenever detected.

### 2.3 Total Time Span of Measurement/Observation

When detected, 1 - 4 minutes, depending on orbital altitude and viewing angle.

### 2.4 Solar Elevation Angle

Initially, observations made in twilight zone. Additional detection possibilities exist in sunlit atmosphere where solar elevation angle generally unimportant.

### 2.5 Cloudiness

Tropospheric clouds not a problem.

### 2.6 Ground Coverage

Not Applicable.

### 2.7/2.8 Resolution and Accuracy Requirements

	<u>Spatial Resolution</u>	<u>Accuracy</u>	
		<u>Spatial</u>	<u>Radiometric</u>
Polarimetry	0.5 deg.	0.05 deg.	10% relative
Photography	0.25 mRad	5 mRad	N/A

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Visible Radiation Polarimeter (VRP)

#### b) Correlative Support

- Pointable Identification Camera

#### c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- Tape Recorders
- CRT Displays.

## SUMMARY EVALUATION

### M2. STELLAR OCCULTATION TO DETERMINE ATMOSPHERIC DENSITY

The proposed experiment is based on a long-term well-established feasibility study conducted at the University of Michigan under NASA sponsorship. The data obtained by the proposed experiment are convertible to information on the global three-dimensional mass distribution of the atmosphere as a function of time. This is of fundamental importance to an observational program aimed at improving weather forecasting and extending the time-range of such forecasts. Such measurements are not possible with present satellite techniques and systems. This Shuttle sortie experiment is viewed as a precursor to an operational system using automated satellites. The experiment tests man's ability to acquire individual stars and hold them in view until a data measurement unit's telescope locks on and tracks them automatically. Operation is restricted to darkness (a period likely to be less demanding of a crew member's time for other experiments) and data can be acquired only above the troposphere. Although this experiment competes with more promising techniques involving co-orbiting unmanned satellites (see M10), it is considered a Level 1 experiment because early implementation is possible and a full definition of measurement/observation requirements can be stated at this time. As its competition (i. e., M10) becomes more fully defined and technologically feasible, it would change to Level 1 and the stellar occultation experiment would be revised downward to a Level 2 importance.

## M2. STELLAR OCCULTATION TO DETERMINE ATMOSPHERIC DENSITY

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas

Upper atmosphere meteorology, weather prediction.

#### 1.2 Experiment Objectives

The primary objective is to test a method for remotely measuring the density of the upper atmosphere by measurement of the refraction of light from occulting stars. Secondly, to compare the atmospheric parameters thus obtained with those acquired by other means in order to verify the theory. Lastly, to supply information on background radiance near the horizon and starlight attenuation in the atmosphere, in order to optimize sensor design for this application.

#### 1.3 Experiment Background

At the present time, numerical weather forecasting is accomplished routinely for periods of three to four days, and covers about one-third of the earth. Further extension of forecasting in time and area will require knowledge of the initial state of the atmosphere on a hemispheric and, eventually, on a global basis.

Most weather prediction models depend on a knowledge of the initial flow and mass distribution of the atmosphere and use primarily the height field of standard pressure surfaces. The usual way to obtain the mass distribution of the atmosphere is to measure, in situ, by radiosonde balloons, the temperature as a function of pressure; and to integrate upward from the surface to obtain pressure as a function of height.

From a spacecraft, the desired pressure-height field can be derived from accurate density and absolute height data. The vertical temperature profiles can be derived by measuring the atmospheric radiance in a number of narrow spectral intervals within the infrared absorption band of a uniformly mixed atmospheric constituent, such as CO<sub>2</sub>.

The potential of a global system of measuring density from space, for such programs as the World Weather Watch and the Global Atmospheric Research Program, has been examined by individual researchers

and groups under the sponsorship of NASA, ESSA, and COSPAR. To date, only analytical and feasibility studies have been completed. The next step requires orbital testing.

Measurement of atmospheric density from space can be inferred from stellar occultation by the intervening atmosphere. In this experiment, stars will be acquired slightly above the horizon and tracked with a star-tracking telescope until occultation occurs. The refraction angle measured as a function of time during occultation can be determined as a function of the ray path constant at the point of tangency. This will permit inversion of the data to deduce the atmospheric density profile in the lower stratosphere and at times in the upper troposphere.

Highly accurate star tracking under excellent viewing conditions is presently a straightforward technique. The proposed experiment is based on a long-term well-established feasibility study conducted at the University of Michigan under NASA sponsorship.

The proposed experiment is required to verify the theoretical results of signal attenuation, background radiance, scintillation, anticipated refraction and startracker performance.

This experiment requires orbital testing because:

- 1) Under less-than-orbital conditions occultations occur too slowly
- 2) The mathematical inversion of the refraction data to determine atmospheric density requires that the sensor acquire the full ray
- 3) The background radiance must be viewed from above the airglow layer in order to be representative.

#### 1.4 Proposed Technical Approach

Stars upon which refraction measurements are to be made will be acquired with an acquisition telescope a few degrees above the horizon. When the star is tracked to within one minute of arc of the center, control will be shifted to a data telescope that will track to its center (within a few seconds of arc). Gyros mounted on the telescope will measure the tube's motion as the star is automatically tracked, until finally the light from the star is occulted by clouds or the earth.

Refraction angles to be measured range from about 4 arc-sec at 50 km tangent height to about 40 min at 5 km. Tracking time, depending on altitude of acquisition and azimuth angle, will be about 20 to 40 sec/ per star. Stars having azimuths within about 30 deg of directly aft will be used in this experiment.

Given the refraction angle measured as a function of time during occultation, together with satellite ephemeris data, the refraction angle will be known as a function of the ray path constant at the point of tangency. The vertical atmospheric density profiles derived from the refraction angles will allow derivation of the vertical profiles of pressure and temperature. They will be compared with radiosonde data taken over meteorological truth sites.

As an adjunct to this experimental approach, data will be gathered in order to supply information on background radiance near the horizon and on starlight attenuation in the atmosphere in order to evaluate performance and optimize further development of the star tracker.

#### 1.5 Relevancy of Experiment

Data on the global three-dimensional mass distribution of the atmosphere as a function of time are of fundamental importance to an observational program aimed at improving weather forecasting and extending the time-range of such forecasts. Such measurements are not possible with present satellite techniques and systems. This Shuttle Sortie experiment is viewed as a precursor to an operational system using automated satellites.

#### 1.6 Role of Man

The observer/astronaut will be required to acquire various stars with a boresighted viewer, holding each star in turn until it is within a 1 degree field-of-view of the acquisition telescope when the data measuring unit's telescope locks on and tracks automatically. The astronaut will monitor the zero-reader on a control panel which indicates gimbal errors, maintaining the Shuttle attitude within prescribed bounds of the established star line. With four or five stars being tracked/orbit and with approximately six minutes of the astronaut's time required for each acquisition and data take, 24 to 30 minutes of his time per orbital period will be required.

### 1.7 Impact of Experiment on Shuttle Sortie Mission

This experiment will require a trained scientist to derive densities and profiles from knowledge of the star, its brightness magnitude, and the speed and degree of occultation. The experiment's success will depend on the performance of the crew in providing supporting information. In order to assess initial performance of the instruments, it will be important to telemeter initial data to the ground for rapid processing. The experiment is conducted during periods when the sun is below the horizon.

### 1.8 Supporting Research and Technology Required

Accurate determinations must be made of the effects of varying air masses, moisture and aerosol distributions and amounts, and the influence of temperature inhomogeneities and scintillations. Effect of scattered moonlight must be determined.

### 1.9 Targets

Stars with brightness magnitude to 5. Four or five star trackings per orbit.

### 1.10 Truth Sites

Existing radiosonde stations (to be selected). Radiosonde data to be near-concurrent with Shuttle-acquired data for comparison purposes.

### 1.11 Orbital Parameters

- 1) Altitude: No preferred altitude; 100 - 300 n. mi. acceptable
- 2) Inclination:  $\geq 45$  degrees preferred; 30 to 45 degrees acceptable
- 3) No requirement for a circular orbit.

### 1.12 Data Required by Investigator

Stellar refraction along two axes, tape recorded as a function of time. Shuttle ephemeris to give position as a function of time. Radiosonde measurements from existing (or augmented) ground station network along the star tracker line-of-sight but, more particularly, as close as

possible to the tangent point of the tracker line-of-sight and the earth's atmosphere. Telemetry of initial data to ground for rapid processing is important in assessing initial performance of instrumentation. Otherwise, delivery time to investigator is not critical.

#### 1.13 Principal Users

Researchers in modeling global circulation of the atmosphere, numerical weather prediction programs.

#### 1.14 Documentation/References

Most of the relevant feasibility studies relating to this experiment have been carried out at the University of Michigan during the 1960s. (See, for example, "Sounding the Atmosphere by Refractive Techniques," F. F. Fischbach, September 1962, as reported in the Second Symposium on Remote Sensing of Environment, October 1962, Ann Arbor, Michigan.

Numerical experiments in long-range weather prediction are being carried out at NOAA, UCLA, and NCAR.



## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION REQUIREMENTS

### 2.1 Time of Year/Season

No preference.

### 2.2 Frequency of Measurement/Observation

Four or five stars per orbit.

### 2.3 Total Time Span of Measurement/Observation

Depending on altitude of acquisition and azimuth angle, 20 - 40 seconds/star. Acquisition plus tracking time per star will be approximately six minutes.

### 2.4 Solar Elevation Angle

Not applicable.

### 2.5 Cloudiness

Not critical.

### 2.6 Ground Coverage

Not applicable.

### 2.7/2.8 Resolution and Accuracy Requirements

	<u>Resolution</u>	<u>Accuracy</u>
Measurement of optical line-of-sight with respect to gyro-stabilized inertial reference frame of star tracker instrument	1 arc-sec rms	2 arc-sec rms
Measurement of angular position of optical line-of-sight to spacecraft coordinates	Not Critical	Not Critical
Determination of spacecraft location	N/A	Normal Ephemeris Accuracy
Determination of spacecraft attitude	Not critical	Not Critical

## 2.9 Shuttle Instrumentation/Equipment Requirements

### a) Primary Instruments

- Star Tracking Telescope, to measure rate of change in refraction of optical line-of-sight to star (slaved and boresighted visual acquisition telescope and star-field camera, rate-gyro stabilized coarse and fine automatic star tracking telescopes)

### b) Correlative Support

- Correlative meteorological data from radiosondes

### c) Support Equipment

- CRT Display
- Tape Recorder (to record change in refraction angles on two axes in conjunction with recording of time).

## SUMMARY EVALUATION

### M3. GLOBAL THUNDERSTORM AND LIGHTNING ACTIVITY

The feasibility of this experiment has been established by number of studies.

Data gathered by this experiment are necessary to provide information on the spatial and temporal distribution of global thunderstorm activity in the atmosphere. Information on the spatial and temporal variations of thunderstorm activity has both basic research and applied values. Among basic research problems are those of the general atmospheric circulation and the vertical distribution of atmospheric contaminants, since it is believed that the large cumulonimbus clouds of intense thunderstorms play a vital role in exchanges between the stratosphere and the troposphere.

Some practical applications are non-meteorological and include location of electrical discharges as an aid in forestry management (fire hazard), in assessing the need for protecting electrical power transmission lines, in enabling optimum safe routing of aircraft, and in estimating atmospheric noise interference to radio-communication. An especially interesting application is the possibility of remotely locating tornadoes, identifiable since they may produce a very much higher lightning flashing rate than do conventional thunderstorms.

This experiment is viewed as precursory to routine automated satellite observations of sferics. However, before such observations become routine, the Shuttle sortie experiment will be very helpful because:

- 1) Visual observations by the astronaut will aid greatly in interpretation of the emissions.
- 2) A relatively low inclination orbit will pass over regions of the earth in which much convective activity may be expected.
- 3) The orbital altitude can be sufficiently low to obtain sufficient signal strength for reliable detection.

This experiment is rated Level 1 for MEO Shuttle Sortie Missions.

### M3. GLOBAL THUNDERSTORM AND LIGHTNING ACTIVITY

#### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

##### 1.1 Associated Problem Areas

Mesoscale meteorology, weather prediction.

##### 1.2 Experiment Objectives

To develop a technique leading to the use of electromagnetic wave emissions (sferics) from the atmosphere to provide data on the spatial and temporal distribution of thunderstorm activity on a global basis; to investigate convective clouds, radio noise other than the lightning associated sferics.

##### 1.3 Experiment Background

During the past several years, a number of studies have dealt with the feasibility of detecting sferics from earth-orbiting satellites.<sup>1-4</sup> Recent observations of UHF emissions from cumulus clouds from both airborne and ground-based equipment indicate that there is adequate power in UHF sferics for detection at satellite altitudes.<sup>4</sup> Astronauts have heard sferics in their UHF communications equipment.

Kirkwood<sup>1</sup> indicates that the best frequencies for detecting sferics appear to be either in the range of 1.5 to 2 times the critical frequency of the F2 layer (an operating frequency in the range of 6 to 20 MHz) or at a higher frequency of about 300 MHz.

For operation at a frequency of 1.5 to 2 times the F2 critical frequency, several different frequencies in the range of 6 to 20 MHz should be detected by the satellite's receiver. The observed data would be relayed to the ground, where the frequency that comes closest to desired range of about 1.5 to 2 times the predicted F2 critical frequency at the point of observation would be used to estimate the thunderstorm activity. In this way the ionosphere itself can be used to limit the field of observation with the result that a very simple antenna can be used on a Shuttle, and its orientation need not be controlled. The disadvantage of this system is that the accuracy of the result depends on the accuracy with which the properties of the ionosphere can be estimated. Thus, the result may sometimes be in error by a factor of as much as 2. Although this error may not always be important, it must be considered.

For operation at the higher frequency of about 300 MHz, the Shuttle would use a directional antenna which must then be properly oriented so that the antenna is pointed downward, thus increasing the complexity of the system. On the other hand, the resulting estimates of thunderstorm activity will be essentially independent of any knowledge about the ionosphere and for this reason should be more reliable than the estimates made at lower frequencies.

#### 1.4 Proposed Technical Approach

UHF, VHF and HF emissions from appropriate targets (see 1.9) in the 610 MHz, 300 MHz, and 6 - 20 MHz frequency range will be measured by equipment consisting of antenna systems, low-noise receivers, signal processing units, a data tape recorder and a control panel. The experiment will be operated with supporting observations by the astronaut. During the daytime, they will include cloud-scene information (e. g., type, form, distribution, and amount).

In addition to photographing the scene, the observer will also monitor lightning, using a viewer fitted with a narrow spectral-band filter around the hydrogen-alpha line ( $6563 \text{ \AA}$ ), which is practically absent in the solar spectrum because of absorption in the solar atmosphere.

During the night-time, visual observation of lightning (e. g., bolts, and frequency and length of discharge) will be made. Simultaneous aircraft, ground, and meteorological satellite observations will also be obtained for postflight correlation and analysis.

#### 1.5 Relevancy of Experiment

These data are necessary to provide information on the spatial and temporal distribution of global thunderstorm activity in the atmosphere. Information on the spatial and temporal variations of thunderstorm activity has both basic research and applied values. Among basic research problems are those of the general atmospheric circulation and the vertical distribution of atmospheric contaminants, since it is believed that the large cumulonimbus clouds of intense thunderstorms play a vital role in exchanges between the stratosphere and the troposphere.

Some practical applications are non-meteorological, and include location of electrical discharge as an aid in forestry management (fire hazard), in assessing the need for protecting electrical power transmission lines, in enabling optimum safe routing of aircraft, and in estimating atmospheric noise interference to radio-communication. An especially interesting application is the possibility of remotely locating tornadoes, identifiable since they may produce a very much higher, lightning flashing rate than do conventional thunderstorms.

The characteristics of non-lightning associated sferics emanating from convective clouds may be related to the rate of vertical development of such clouds so that such observations may prove to be of diagnostic value and may be useful as an index of the intensity of convection.

This experiment is viewed as precursory to routine automated satellite observations of sferics. However, before such observations become routine, the Shuttle sortie experiment will be very helpful because:

- 1) Visual observations by the astronaut will aid greatly in interpretation of the emissions.
- 2) A relatively low inclination orbit will pass over regions of the earth in which much convective activity may be expected.
- 3) The orbital altitude can be sufficiently low to obtain sufficient signal strength for reliable detection.

#### 1.6 Role of Man

UHF, VHF and HF emission measurements made aboard the Shuttle will be compared with: a) visual reports and observations of cloud cover by the astronaut, b) photography supplied by on-board television equipment, c) photographs of the surface taken by the astronaut, and d) surface observations of convective cloud development.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

A continuous monitoring of predicted thunderstorm areas may be required, resulting in extended crew-duty cycles. Observations will require a significant amount of crew participation in voice annotations and in recording data and calibrations over ground truth sites.

## 1.8 Supporting Research and Technology Required

Different states of convective activity, i. e., ranging from non-precipitating cumulus clouds to severe thunderstorms and tornado-producing clouds have different sferics characteristics and signatures. It will be necessary to develop descriptive and mathematical models based on accumulated experimental data and theoretical considerations in order to relate sferics signatures to their respective sources and dynamic atmospheric processes. In this connection, existing knowledge regarding sferics possibilities from a Shuttle can be enhanced by a comparison of radio noise data already taken in satellites with low-level cloud and thunderstorm information.

## 1.9 Targets

Cumulus-type clouds typical of convective activity, thunderstorms, line squalls, and severe storms (hurricanes, tornadoes, tropical storms, etc.). Targets are mostly targets of opportunity.

## 1.10 Truth Sites

A generally cloud-free area (e. g., Southwestern U.S.) for locating a portable ground station, to be used for calibrating signals from ground to Shuttle. Although most observations will be from targets of opportunity, locations where sferics equipment is already emplaced for other purposes (e. g., Cape Kennedy) can be used for truth sites.

## 1.11 Orbital Parameters

- 1) Altitude: 100 - 200 n. mi. ; <400 n. mi. acceptable
- 2) Inclination: 50 degrees desirable; 30 degrees acceptable
- 3) Eccentricity: Circular orbit.

## 1.12 Data Required by Investigator

Tape-recorded data together with Shuttle position, altitude, and attitude data will be required for subsequent analysis. In addition, the visual and photographic observations made by the astronaut will be required for comparison with the analysis and as an aid to interpretation of the data. Ancillary IR information (from other onboard equipment, surface observations, or from meteorological satellites) to give cloud-top altitudes will be particularly valuable in evaluating the possible diagnostic use of sferics data.

### 1.13 Principal Users

Primarily, those concerned with numerical modeling of the general circulation of the atmosphere, mesoscale phenomena, and cloud physics. Direct and immediate use will be made in weather forecasting, radio-communications, aircraft flight planning and in forest fire prevention and control activities.

### 1.14 Documentation/References

1. R. L. Kirkwood, "Determination of Thunderstorm Density by Radio Observations from a Satellite," RM-4417-NASA, The Rand Corporation, January 1965.
2. R. L. Kirkwood, "The Effective Directivity of an Isotropic Antenna Looking Down Through the Ionosphere," RM-4949-NASA, The Rand Corporation, July 1966.
3. E. T. Pierce, "Sferics," in Atmospheric Exploration by Remote Probes, Proceedings of the Scientific Meetings of the Panel on Remote Atmospheric Probing, Vol. 2, National Academy of Sciences/National Research Council, January 1969.
4. University of Wisconsin (S. A. Rossby et al), "Proposal to NASA for SO48 UHF Sferics Detection," October 1966.



## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION REQUIREMENTS

### 2.1 Time of Year/Season

Summer for thunderstorm activity, Spring and Autumn for severe storms (tornadoes and hurricanes), Winter for extra-tropical storm systems.

### 2.2 Frequency of Measurement/Observation

Observations are transitory, "second looks" unlikely, except in case of tropical storms and hurricanes.

### 2.3 Total Time Span of Measurement/Observation

20 to 30 minutes/observing period, allowing Shuttle to go from radio horizon, over region of interest, to the radio horizon.

### 2.4 Solar Elevation Angle

No sun-angle requirements.

### 2.5 Cloudiness

Cloud cover required; no upper limit.

### 2.6 Ground Coverage

Not applicable.

### 2.7 Resolution

~100 meters for cloud photography.

### 2.8 Accuracy/Precision

Location accuracy of sferics  $\leq 100$  n. mi.

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Sferics Receiver

#### b) Correlative Support

- TIROS-N Operational Vertical Sounder (TOVS)
- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Pointable Identification Camera

c) Support Equipment

- Tracking Telescope
- CRT Display
- Tape Recorders.

## SUMMARY EVALUATION

### M4. AIR POLLUTION MONITORING

This experiment addresses both gaseous and particulate air pollution problems and aims at establishing an experimental basis for global and regional monitoring of pollutants from space.

The complement of five pollution sensors will be used in several measurement modes, viz., earth-pointing, limb-scanning, and sun or stellar occultation. The potential afforded by simultaneously operating sensors to obtain combined data sets for sensor comparison is a large plus and is not likely to be possible on any but a Shuttle sortie mission payload. Concurrently acquired correlative measurements relating to atmospheric conditions for the same area viewed by the pollution sensors would enhance the experimental design.

Since the sensor payload would be developmental and experimental in nature with each sensor contributing to one or more of a large number of complex and with related problems that have been identified in the meteorological problem area of air pollution and since man will contribute greatly to the success of this experiment (target selection, pointing, visual descriptions, etc.), this experiment is rated Level 1 for MEO Shuttle Sortie Missions.

## M4. AIR POLLUTION MONITORING

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas

Air pollution (gaseous and particulate) ; upper atmosphere meteorology; weather modification and global climatic change.

#### 1.2 Experiment Objectives

To provide a basis for global and regional monitoring of pollutants from space, including the detection, identification and determination of their time varying vertical and horizontal concentrations and distributions.

#### 1.3 Experiment Background

The technical feasibility of using satellites to monitor air pollutants such as  $\text{CO}_2$ ,  $\text{CO}$ ,  $\text{CH}_4$ ,  $\text{N}_2\text{O}$ ,  $\text{NO}_2$ ,  $\text{NH}_3$  and  $\text{SO}_2$  has been studied by a number of investigators<sup>1-4</sup> and a recent report<sup>5</sup> by a working group sponsored by NASA has recommended that satellites be used for studying regional pollution problems and in evaluating techniques for eventual use on satellites. In addition, the panel on particle pollution recommended a program using satellite-borne methods for monitoring atmospheric particles. A number of sensors have been or are being developed for measuring pollutants from space. Several others have been proposed for development. Development has been under the auspices of NASA's AAFE program. Among them are the following:

- 1) Remote Gas Filter Correlation Analyzer – This sensor operates in the IR region, uses a non-dispersive technique and promises to measure a number of gaseous pollutants.
- 2) Correlation Interferometer – Combines absorption spectroscopy with scanning interferometry for measuring carbon monoxide concentrations and for identifying the mechanisms or sinks which remove carbon monoxide from the atmosphere.
- 3) Visible Radiation Polarimeter – Measures the polarization of radiation emerging from the sunlit atmosphere in order to determine atmospheric turbidity. It will also provide an estimate of the corrections in the temperature and humidity profile calculations based on  $\text{CO}_2$  due to particulate matter and aid in the evaluation and correction of earth resources spectral radiances data from different surface features.

- 4) Correlation Spectrometer – Measures the absorption of reflected sunlight in the UV and visible spectrum and optically correlates a gas absorption or emission spectrum against a stored reference spectrum to identify and measure the concentrations of SO<sub>2</sub> and NO<sub>2</sub>.
- 5) High Speed Interferometer – A high resolution Fourier interference spectrometer operating in the IR reflected solar radiation part of the spectrum for monitoring trace molecules.

#### 1.4 Proposed Technical Approach

With the complement of pollution sensors described in 1.3, several measurement approaches will be used:

- 1) Earth oriented – primarily for tropospheric pollutants
- 2) Occultation, sun or stellar oriented – primarily for upper atmospheric pollutants
- 3) Atmospheric, horizon oriented – primarily for upper atmospheric pollutants.

The sensors would be used to identify and measure the amounts of various pollutants and particulates in their fields of view over predesignated targets and targets of opportunity. Combined data sets would be derived from simultaneously operating sensors. The data takes would be supported by concurrently acquired correlative data relating to pertinent meteorological conditions in the atmosphere, such as temperature profile, precipitation distribution, cloudiness, etc. The sensors would be slaved to a target acquisition and tracking telescope system, operated by the astronaut.

The sensor payload for this experiment would be developmental and experimental in nature with each sensor contributing to one or more of a large number of complex and inter-related problems that have been identified in the meteorological problem area of air pollution.

Very importantly this experiment provides a basic capability for continuously measuring air pollutants, both gaseous and particulates, and by virtue of the availability of concurrent meteorological supportive data, will help determine the dynamics of pollutant distribution, dispersal rates, and pollution interactions with the global meteorology. In addition, measurements of pollutant profiles above the troposphere will permit the study of photochemical processes in the stratosphere which may be significant

in the removal of pollutants. Such information will become increasingly valuable in assessing global and regional air quality and will aid in predicting pollution levels.

### 1.5 Relevancy of Experiment

Data gathered will demonstrate the feasibility of performing routine automated measurement of pollution in the atmosphere. Pollution information is required in order to assess and answer questions in a number of problem areas, such as:

- 1) Four-dimensional (3 in space and 1 in time) distribution and concentrations of pollutants presently in the atmosphere (a baseline set of information)
- 2) Detection of cycles and trends
- 3) Sources and sinks of pollutants and their removal mechanisms
- 4) Behavior of pollutants in the atmosphere (physical and chemical).

### 1.6 Role of Man

The generally small spatial coverage of the numerous sensors implies that to use them optimally they must only be pointed at those targeted areas of greatest interest. While directed selections of targets may be made from the ground, overriding considerations will be given to the observer's choices based on visual or other evidence available to him (e. g., cloud-free areas, smoggy regions, etc.). Sensors will be bore-sighted and/or slaved to a tracking telescope, to be used for target acquisition and tracking by the astronaut. The observer will be in frequent communication with the ground, particularly during, preceding, and following pollution episodes.

### 1.7 Impact of Experiment on Shuttle Sortie Mission

Tracking telescope boresighted to the instruments' fields-of-view will be used by the astronaut to keep a particular target in the earth-atmosphere system in the field-of-view. Many observations will derive from targets-of-opportunity. Data collection by the sensors will be augmented by voice annotations from the crew. Near-real time responsiveness to pollution episode reporting will be required.

### 1.8 Supporting Research and Technology Required

- Sensor development and measurement technique improvements
- Data analysis and interpretation
- Mathematical model improvements, including computer simulation techniques
- Research in chemical kinetics to establish rate constants and quantum yields of thermal and photochemical reactions of importance in the atmosphere
- Research on role of aerosols in the radiation balance, including radiation characteristics of aerosols.

### 1.9 Targets

Urban areas, e. g., Los Angeles, Chicago, New York, etc. ;

Interurban areas, e. g., Washington-Philadelphia-New York-Boston,  
Chicago-Detroit, San Francisco-Los Angeles-  
San Diego, etc. ;

Rural areas, e. g., Kansas, Nebraska, Iowa, etc.

### 1.10 Truth Sites

Choice of truth sites should be closely related to the availability of an adequate ground monitoring network to include both air sampling and meteorological instrumentation. Priority should be given to urban areas, followed by interurban and rural areas.

### 1.11 Orbital Parameters

- 1) Altitude: 100 n. mi. preferred; 200-300 n. mi. acceptable
- 2) Inclination:  $\geq 50$  degrees desirable; less than 35 degrees not acceptable
- 3) Eccentricity: Circular orbit.

### 1.12 Data Required by Investigator

Tape recorded data plus real-time readouts of measurements transformable to represent the presence or absence of a particular gaseous constituent and its concentration. Evaluation, analysis and correlation

of these data will require information on current and past meteorological conditions, pollutant source characteristics and time of day/night; photographic record of scene coincident with sensors' fields-of-view; sensor attitude relative to solar incidence angle.

### 1.13 Principal Users

EPA, NOAA, USDA, USDI, other government agencies; regional, state, and local planning and enforcement agencies. Researchers concerned with atmospheric and climatic effects and relationships, health effects, etc.

### 1.14 Documentation/References

1. C. B. Ludwig, R. Bartle, and M. Griggs, "Study of Air Pollution Detection by Remote Sensors," NASA CR-1380, July 1969.
2. R. N. Grenda, M. H. Bortner, P. J. LeBel, J. H. Davies, and R. Dick, "Carbon Monoxide Pollution Experiment (I). A Solution to the Carbon Monoxide Sink Anomaly," AIAA Paper 71-1120, Presented at Joint Conference on Sensing of Environmental Pollutants, Palo Alto, California, November 1971.
3. A. R. Barringer, "Investigations in Correlation Spectroscopy and Interferometry for the Remote Monitoring of Air Pollution," AIAA Paper 71-1105, Presented at Joint Conference on Sensing of Environmental Pollutants, Palo Alto, California, November 1971.
4. R. A. Toth and C. B. Farmer, "Global Survey of Atmospheric Trace and Pollutant Molecules," Presented at XXIIInd International Astronautical Congress, Brussels, Belgium, September 1971.
5. Remote Measurement of Pollution, A Report of a Working Group Sponsored by NASA, and convened at Norfolk, Va., August 1971, NASA SP-285, 1971.
6. Z. Sekera, "Determination of Atmospheric Parameters from Measurement of Polarization of Upward Radiation by Satellite or Space Probe," RM 5158-PR, The Rand Corporation, October 1966.
7. Z. Sekera, et al, "Visible Radiation Polarization Experiment," Interim Report for NASA Contract NAS 1-10107, Space Studies Center, Institute of Geophysics and Planetary Physics, UCLA, October 15, 1971.



## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION REQUIREMENTS

### 2.1 Time of Year/Season

All seasons, with priority to Autumn months over eastern U.S. and Summer months over extreme western U.S.

### 2.2 Frequency of Measurement/Observation

Daytime observations over targets are dependent on meteorological conditions and source emission characteristics. During periods when pollutant concentration are high, observation should be made as frequently as possible.

### 2.3 Total Time Span of Measurement/Observation

For daytime observations, depending on areas to be observed, cloud cover and solar angle, 10 min/orbit is a likely maximum. Solar occultations may take approximately 1-minute, depending on orbital path.

### 2.4 Solar Elevation Angle

For daylight observations, solar angle >30 degrees.

### 2.5 Cloudiness

Instantaneous field-of-view should be free of clouds to maximize data acquisition. To be determined is the fraction of targeted data that may be cloud-covered before acquired data is not useful.

### 2.6 Ground Coverage

Various, depending on individual sensor, whether scanning or not; swath widths for scanning modes may be of the order of 100 n. mi.

### 2.7 Resolution

Depending on sensor used, from 1-1/2 to 8 n. mi. for orbital altitude of 100 n. mi.

### 2.8 Accuracy/Precision

Target location accuracy 1 to 3 n. mi. depending on sensor used. Accuracy variable, depending on sensor and concentration of gaseous constituents or particulates.

## 2.9 Shuttle Instrumentation/Equipment Requirements

### a) Primary Instruments

- Remote Gas Filter Correlation Analyzer (RGFCA), to measure concentrations of CO, CO<sub>2</sub>, N<sub>2</sub>O, NO<sub>2</sub>, NH<sub>3</sub>, and CH<sub>4</sub>
- Carbon Monoxide Pollution Experiment (COPE)
- Visible Radiation Polarimeter  
to measure concentration of particulate pollutants
- Air Pollution Correlation Spectrometer, to measure concentration of SO<sub>2</sub> and NO<sub>2</sub>
- High Speed Interferometer (HSI), to measure concentrations of CO, NO, NO<sub>2</sub>, SO<sub>2</sub>, NH<sub>3</sub>
- Advanced Limb Radiance Inversion Radiometer (ALRIR), to obtain data on temperature structure and water vapor and ozone distribution in the stratosphere
- UV Upper Atmospheric Sounder, to measure altitude profiles of O<sub>3</sub> and NO in the upper atmosphere.

### b) Correlative Support

- TIROS-N Operational Vertical Sounder (TOVS)
- TIROS-N Advanced Very High Resolution Radiometer (AVHRR)
- Passive Multichannel Microwave Radiometer (PMMR)
- Pointable Identification Camera (70 mm).

To be used with VRPM experiment only, in target tracking mode. Panchromatic film and red optical filter.

- Data Collection System

### c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- Tape Recorder
- CRT Display.

## SUMMARY EVALUATION

### M5. WEATHER MODIFICATION EXPERIMENTS - TROPICAL STORMS

Many aspects of weather-modification research can benefit from the unique ad hoc observational capabilities of man. It is apparent that at some time in the future, under the proper safeguards, man will, in all probability, conduct large-scale modification experiments in the atmosphere. At these times, the overall view provided by a trained man observing the event in its entirety will be invaluable.

The example of the recent and continuing experiments in seeding hurricanes serve as an example for this experiment, since in the long run the most effective way to cope with such storms may be by their modification using aircraft, rocket or satellite seeding (with rockets) techniques. Since hurricanes are notoriously changeable and unpredictable, a major problem will be to prove that the seeding effects actually cause changes that may occur. The programmed use of the Shuttle on sortie missions to carry out direction of the conduct of modification experiments and to observe and aid in the correlation of experimental results puts this experiment on Level 1 for consideration as a Shuttle sortie mission experiment.

## M5. WEATHER MODIFICATION EXPERIMENTS – TROPICAL STORMS

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas

Weather and climate modification and control, weather forecasting, severe storm phenomenology, disaster avoidance, air-sea interactions.

#### 1.2 Experiment Objectives

- Aid in the direction of large-scale atmospheric (hurricane) modification experiments
- Evaluate the effects of modification efforts, by providing intensive high resolution multisensor/multispectral measurements and visual observations prior to, during, and following hurricane modification activities.

#### 1.3 Experiment Background

During the past decade, research effort in weather modification has resulted in important achievements in the following areas:

- a) Modifying the Dynamics of Convective Clouds – Numerical models have been developed that allow their use in predicting the dynamic effects of the release of latent heat from ice crystal growth initiated by seeding. Experimental designs for seeding operations intended to modify the location and intensity of updrafts and the height of cloud tops have been carried out by numerical methods. Initial field tests using such models have already produced positive results relative to the increase in height of the tops of convective clouds that have been seeded with ice nuclei.
- b) Precipitation Modification – Randomized experiments have indicated that ice-nuclei seeding may, for some types of clouds and storm systems, and in some situations, lead to precipitation increases of 10 to 30 percent. In other situations, such seeding has either led to comparable decreases in precipitation or has had no measurable effect. The characteristics that distinguish increases from decreases seem to be linked to temperature and wind distributions and to the stability of the cloud environment, but the full role of these characteristics influencing the effects of seeding remains to be explained.
- c) Fog Dissipation – The seeding of super-cooled fog with dry ice, silver iodide or liquid propane is an operational practice at several airports in the U.S., USSR, and France. Dissipation appears to be successful in 60 to 80 percent of the cases. Since supercooled fogs constitute only about 5 percent

of the fogs occurring at airports in the conterminous U. S., increasing efforts have been aimed at dissipation of warm fogs. Success to date has been limited, and no proven practical operational method for dissipation exists.

- d) Hail Suppression — Widespread efforts to alleviate damage caused by hailstorms center on the introduction of seeding agents (large numbers of ice nuclei) directly into the super-cooled region of clouds by rockets or artillery shells. Investigators in the Soviet Union have reported notable successes over a period of years in protecting crops from destruction from hail; results from other countries including the U. S. have been mixed. The National Hail Research Experiment has been organized and will begin field operations in 1972, under the management of the National Center for Atmospheric Research (NCAR).

Using carefully designed field experiments, this program will test the feasibility of reducing hail damage by seeding.

- e) Modifying the Dynamics of Hurricanes — The development of hurricanes following specific modes of seeding have been simulated for simple, circularly symmetrical numerical models of hurricanes. These experiments have suggested that significant effects may result from seeding. Project Stormfury's field test on Hurricane Debbie in August 1969 indicated that decreases of maximum wind speeds of 15 to 30 percent followed silver iodide seeding. Such limited results suggest the possibility of reducing damage inflicted by hurricanes (and other tropical storms) and possibly influencing the path taken by them. Because of the great potential value of such efforts, the Committee on Atmospheric Sciences of the National Research Council/National Academy of Sciences has recommended that more realistic hurricane models be developed and that further careful field tests of model predictions be carried out.<sup>2</sup>

In recent years, a wholly new capability to monitor the ocean in order to detect and track these storms has been provided by weather satellites, especially by the geosynchronous ATS. Such observations have also been used effectively to plan reconnaissance aircraft missions in probing storm centers.

Although further improvements will come about in the already excellent hurricane forecasting and warning system, in the long run the most effective way to cope with such storms may be by their modification using aircraft seeding techniques. Since hurricanes are notoriously changeable and unpredictable, a major problem will be to prove that the seeding effects actually cause changes that may occur. The programmed

use of the Shuttle to carry out direction of the conduct of modification experiments and to observe and aid in the correlation of experimental results seems warranted for consideration as a Shuttle sortie mission experiment.

#### 1.4 Proposed Technical Approach

The proposed experiment will provide intensive high resolution multisensor multispectral observations and measurements of the three-dimensional hurricane structure prior to, during and following modification efforts. The most likely area for study and seeding activities will be determined on the basis of combined Shuttle/ground information. Fully coordinated in situ measurements will be conducted from ground, aircraft, sea, and balloon-borne platforms. Seeding materials may be dispersed by rocket, aircraft, or possibly the Shuttle itself.

Mission scheduling and the choice of orbital parameters will take advantage of early hurricane monitoring and tracking afforded by geosynchronous meteorological satellites. Thus, the Shuttle sortie mission could be optimized to provide long and repeated viewing times over a period of up to five days. Equipment could consist of a broad spectrum of sensors operating in the visible, infrared, and microwave portions of the spectrum. Photography available from the Shuttle will be highly detailed, with multi-angled views over the same scene. These will be correlated with other sensors taking data over the same scene. A tracking telescope will provide the observer with high resolution visual observations.

Parameters to be measured or derived will include cloud visual and optical properties, cloud top temperature/pressure, cloud liquid water content/drop size parameterization, sea surface temperature, sea state, precipitation, vertical temperature profile, and sferics.

#### 1.5 Relevancy of Experiment

Along with the study of hurricanes, many aspects of weather-modification research can benefit from the unique ad hoc observational capabilities of man. It is apparent that at some time in the future, under the proper safeguards, man will, in all probability, conduct large-scale modification experiments in the atmosphere. At these times, the overall

view provided by a trained man observing the event in its entirety would be invaluable. The example of the recent and continuing experiments in seeding hurricanes serve as an example. If man had been in orbit observing such events he could have, first of all, reported in detail his impression of what was happening. He could have assembled the same photographs that would have been available from an unmanned satellite (i. e., the ATS), but with the additional ability to point his cameras accurately at a specific small area, he could have used lenses of longer focal length and higher resolution. He could have performed a similar function with radiation sensors, obtaining high resolution in the specific areas of interest (and at some specific wavelengths). These ascribed capabilities, of course, assume that the man was positioned at the right place at the right time, and that his total viewing time (possibly involving more than one pass over the area) was such as to permit him to observe the event over a significant portion of its life cycle. These potentials are afforded by the Shuttle sortie mission.

#### 1.6 Role of Man

The role of the astronaut will be to adjust, calibrate and set up the various instruments (cameras, radiometers, etc.) required for the observational program, select the most likely area(s) for seeding and study, communicate directly with participating elements on the ground and in the air, record and help analyze and interpret Shuttle-acquired observations.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

This experiment will require close coordination with combined air-sea-land support elements. The sortie mission will require a launch readiness having short reaction times to orbit once a potential modification situation is identified (~one week or less prior to seeding attempts). Once the sequence of operations is initiated for this experiment, it will take the highest priority for data-taking during all other experiments making up the sortie payload. In order to assess initial results of the seeding, it will be important to verbally communicate visual observations to the ground. The success of the experiment will depend greatly on the performance of the crew in providing both direct and correlative observations and measurements.

## 1.8 Supporting Research and Technology Requirements

- More realistic numerical models of hurricane must be developed in order to simulate with high-speed computers that development of hurricanes following specific modes of cloud seeding
- Improved methods for the the early determination of the potential for specific tropical storms to develop into hurricanes amenable to modification
- Continued improvements in systematic investigation of the dynamic effects that can be produced by cloud seeding to determine whether hurricane winds can be reduced and the hurricane paths changed
- Substantially increased research efforts in cloud physics and weather modification to be carried out in university, private and government laboratories.

## 1.9 Targets

Hurricanes in the NorthAtlantic, Gulf of Mexico and Caribbean are primary target areas. (The possibility of conducting tests in the Pacific should be considered.)

## 1.10 Truth Sites

Whenever feasible, existing surface and upper-air radiosonde observational facilities should be used, augmented by an additional network of similar observations from aircraft (e.g., dropsondes) ships and balloons. Fixed truth sites not feasible.

## 1.11 Orbital Parameters

Altitude: >200 n. mi. preferred; 200 - 400 n. mi. acceptable.

Inclination: Variable, generally less than 30 degrees.

## 1.12 Data Required by Investigator

Foreward, aft, and side oblique photography, to include stereo pairs, whenever possible; radiometric data reduced to indicate the spatial and temporal distribution of sea surface temperature, sea state, cloud tops, temperature/pressure, cloud liquid water content and drop size parameterization, the vertical temperature profile, precipitation, cloud optical properties; sferics; verbal descriptions of visual observations and descriptions by astronaut; Shuttle position, altitude and attitude data.



### 1.13 Principal Users

National Oceanographic and Atmospheric Administration (NOAA), National Center for Atmospheric Research (NCAR), US Navy, NASA, atmospheric scientists concerned with numerical modeling, tropical storm analysis, weather modification and control, etc. (e.g., Florida State University, MIT, UCLA, etc.).

### 1.14 Documentation/References

1. R. C. Gentry, "Hurricane Debbie Modification Experiments," Science 168, pp 473-475, 1970.
2. National Academy of Sciences/National Research Council, The Atmospheric Sciences and Man's Needs: Priorities for the Future, Washington, D. C., 1971.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION REQUIREMENTS

### 2.1 Time of Year/Season

For Gulf of Mexico, Caribbean, and nearby waters and coasts:  
Late Summer through mid-Autumn.

### 2.2 Frequency of Measurement/Observation

At least once prior to, during, and following seeding. Optimum would be 2 to 3 consecutive orbital "looks" each day of mission.

### 2.3 Total Time Span of Measurement/Observation

3 - 6 minutes per orbital pass for 200 n. mi. altitude.

### 2.4 Solar Elevation Angle

For daytime observations,  $\geq 25$  degrees.

### 2.5 Cloudiness

Not applicable.

### 2.6 Ground Coverage

$\pm 60$  degrees from nadir for radiometric sensors and sferics receivers;  $\pm 75$  degrees for photographic systems.

### 2.7 Resolution

Visible photography, 200 - 500 ft., IR and microwave, variable depending on sensor.

### 2.8 Accuracy/Precision

Accuracy of location of center to  $\leq 1$  n. mi.

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Cloud Physics Radiometer
- Passive Multichannel Microwave Radiometer (PMMR).

- IR Multispectral Mechanical Scanner  
(Ocean Surface Temperature Measurement)
  - TIROS-N Operational Vertical Sounder (TOVS)
  - TIROS-N Advanced Very High Resolution Radiometer  
(AVHRR)
  - Sferics Receiver
- b) Correlative Support
- Pointable Identification Camera
  - Data Collection System
- c) Support Equipment
- Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Display
  - Tape Recorders.

## SUMMARY EVALUATION

### M6. ICE ON THE SOUTHERN OCEAN

The proposed experiment aims at providing reliable quantitative data on the variations in pack ice extent. Required information includes the location of open leads and polynyas; the distribution and total amounts of pressure ridges, thin ice, and areal percentage of puddles, and the variation in mean areal albedo in summer.

In order to achieve this, this experiment proposes a multisensor, multispectral approach that includes passive multifrequency multipolarization microwave radiometry, high resolution radar, and laser and infrared scanning equipment. The experiment is particularly suited to a 7-day sortie mission since the requirement is not for continuous observations; rather, short period (e.g., 5 - 7 days) continuing (e.g., monthly, seasonal) observation is called for.

The observations obtained will provide an important input to dynamic numerical models which relate the heat gained and lost by the atmosphere and the ocean. The investigation and relationships between Antarctic pack ice extent and global climate is a central theme which should help give coherence and purpose to future programs in Antarctic seas. Such programs will deal principally with investigations of the contemporary interaction between ice extent and global climate, emphasizing cause-effect relationships.

This experiment is considered Level 1 for MEO Shuttle Sortie Missions.

## M6. ICE ON THE SOUTHERN OCEAN

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas

Extended range weather forecasting, air-sea interaction, long-term climatic change, weather modification.

#### 1.2 Experimental Objectives

The basic objective is to provide observational data on the variations in pack ice extent on the Southern Ocean; specifically, the location and extent of pack ice, open leads and polynyas (especially in Winter) and the variation of mean areal albedo in Summer. Such observations will include the distribution of ice and open water in both space and time.

#### 1.3 Experiment Background

About 10 percent of the ocean area in the northern hemisphere is covered by floating ice in winter and in the southern hemisphere the figure is about 13 percent of a larger ocean area. The areal extent of this pack ice varies greatly, not only during the year but from year to year (see Figures 1 and 2). It has long been observed that these variations show a close correlation with many indices of climatic change.

Further, the effectiveness with which an ice cover reduces the ocean/atmosphere heat exchange, coupled with the large annual variation in ice extent on the Southern Ocean, suggests that the variability of ice extent may be an important factor in amplifying the climatic effects of small changes in global heating. The importance of this variable ice extent is that it acts as a sensitive "climatic lever" by regulating heat exchange between the ocean and the atmosphere in both the Arctic and the Antarctic.

In the Arctic the annual variation in the area covered by pack ice is about 20 to 25 percent. In the Antarctic the maximum area of pack ice is more than 1.5 times greater than in the Arctic and the annual variation of ice area is 85 percent of the maximum (from about  $19 \times 10^6 \text{ km}^2$  in September to  $2.6 \times 10^6 \text{ km}^2$  in March). Thus, the annual variation of ice-covered area is some six times greater in the Antarctic than in the Arctic.

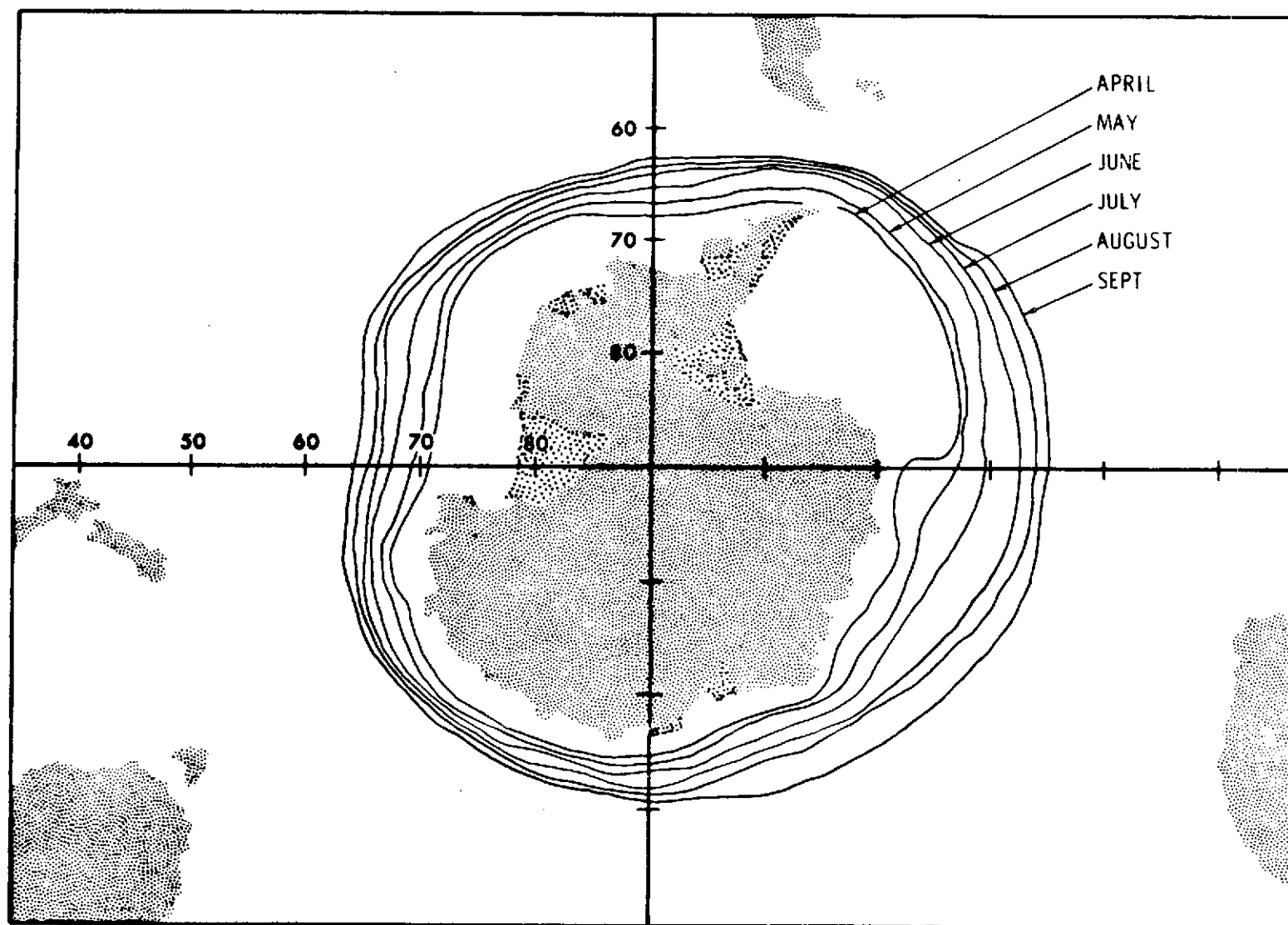


Figure 1. Monthly Variations in the Boundary of the Pack Ice  
(Atlas of Antarctica, 1966).

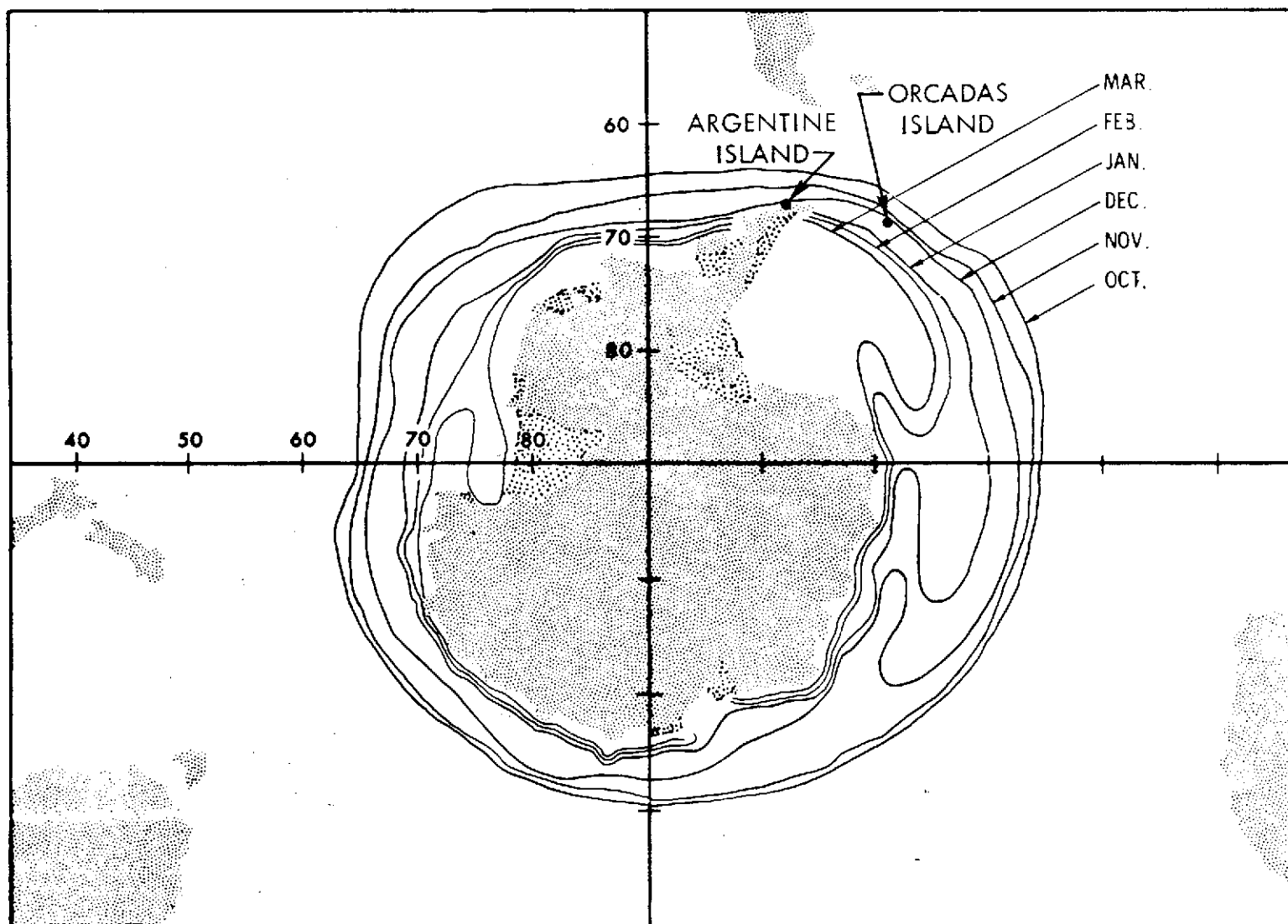


Figure 2. Monthly Variations in the Boundary of the Pack Ice  
(Atlas of Antarctica, 1966).

In studying the nature of global climatic variations, attempts have been made to quantitatively assess the annual and long-term variations occurring in the Antarctic heat-sink region and to relate these variations to variations in global atmospheric circulation. Many of these studies have placed emphasis on the role of variable ice extent on the Southern Ocean in regulating heat exchange between ocean and atmosphere, thereby influencing the thermal forcing of atmospheric circulation.

Since the general atmospheric circulation is forced by uneven distribution of heating between the equator and the poles, variations in equatorial heating and polar cooling are poorly understood and little studied, largely because of the paucity of relevant data over the oceans. Yet, it has been discovered that significant anomalies of ocean/atmosphere heat and moisture exchange do occur and that these anomalies are closely related to variations in the dynamic behavior of the atmosphere.

The North Atlantic was the first ocean area to be studied, followed by the whole Atlantic. In recent years emphasis has shifted to the Pacific where even larger anomalies of ocean/atmosphere heat exchange have been found to occur, both in the equatorial zone and in the mid-latitude North Pacific.

For the Arctic region, anomalies of heat exchange and related variations of atmospheric circulation have been investigated in great detail by Soviet scientists and are now receiving increased attention by the joint US-Canadian-Japanese project AIDJEX (Arctic Ice Dynamics Joint Experiment).

For the Antarctic regions, such studies have not yet gotten underway, largely because adequate data have been lacking. It is here that Shuttle Sortie missions can make a large contribution towards a better understanding of the time and space variations of the ocean/atmospheric heat budget in the Antarctic regions and the relationship between these variations in thermal forcing and the observed variations in the atmospheric circulation.

Monitoring the extent of ice over the Southern Ocean on a continuing basis is an essential task in the development of extended-range weather forecasting and in understanding air-sea interactions.



#### 1.4 Proposed Technical Approach

The proposed experiment aims at providing reliable quantitative data on the variations in pack ice extent. Required information includes the location of open leads and polynyas; the distribution and total amounts of pressure ridges, thin ice, and areal percentage of puddles, and the variation in mean areal albedo in summer.

In order to achieve this, this experiment proposes a multisensor, multispectral approach that includes passive multifrequency multipolarization microwave radiometry, high resolution radar, laser and infrared scanning equipment. With sufficient illumination conditions existing at specific times of year and given the absence of continuous cloud cover, further information can be acquired with wide-angle high resolution photographic systems. Specific regions of the ice pack will be subject to more intensive observations as observing conditions (e.g., cloud cover) permit. The required high inclination orbit would provide repeated passes over a five day period in an attempt to obtain more-or-less complete information. The requirement is not for continuous observations; rather, continuing observation (e.g., monthly) is called for.

#### 1.5 Relevancy of Experiment

The observations obtained will provide an important input to dynamic numerical models which relate the heat gained and lost by the atmosphere and the ocean. The investigation and relationships between Antarctic pack ice extent and global climate is a central theme which should help give coherence and purpose to future programs in Antarctic seas. Such programs will deal principally with investigations of the contemporary interaction between ice extent and global climate, emphasizing cause-effect relationships.

#### 1.6 Role of Man

The role of the astronaut will be to adjust, calibrate and set up the instrumentation required for the observational program. A target acquisition and tracking telescope will be used to visually (when scene illumination conditions are sufficient) observe, describe and characterize various features of the pack ice. Pointing and tracking functions required in the operation of such instruments as a laser altimeter will be accomplished by slaving the instruments to the telescope gimballed platform.

### 1.7 Impact of Experiment on Shuttle Sortie Mission

Because of the geographical location of the ice pack, there will be little competition by other on-going experiments making up a Shuttle sortie payload.

### 1.8 Supporting Research and Technology Requirements

- Supportive research on the physical processes by which heat is exchanged, the resulting growth and dissipation of ice and the related physical effects on ocean and atmosphere will require detailed studies in certain regions.
- Detailed formulation of coordinated field observational programs at the surface and by instrumented aircraft and automated satellites to be operative throughout the year
- Development of objective numerical simulations (as opposed to empirical correlations) of the planetary ocean/atmosphere system in order to better understand the consequences of climatic variations.

### 1.9 Targets

The ice pack on the Southern Ocean, extending at its maximum, poleward to the continent from approximately 55 degrees S at 0 degrees longitude to 60 degrees S at 90 degrees E longitude, to 63 degrees S at 180 degrees longitude and to 63 degrees S at 90 degrees W longitude. Minimally, the pack extends from 65 degrees - 75 degrees S poleward to the continent.

### 1.10 Truth Sites

Supportive correlative data should be taken at established sites such as Orcados, on Laurie Island in the South Orkneys (~65 degrees S latitude).

### 1.11 Orbital Parameters

Altitude:  $\leq 200$  n. mi. preferred; 200 - 400 n. mi. acceptable.

Inclination: 75 degrees for Autumn (March) launches;  
65 degrees for Spring (October) launches.

### 1.12 Data Required by Investigator

Location and extent of pack ice, open leads, polynyas, puddles, thin ice, pressure ridges on a routine monthly or seasonal basis; the mean areal albedo in summer (December-January).

### 1.13 Principal Users

National Center for Atmospheric Research (NCAR), National Oceanic and Atmospheric Administration (NOAA), atmospheric and oceanographic scientists concerned with numerical modeling, general circulation of the atmosphere, weather forecasting and climatic change, air-sea interactions, and global meteorology.

### 1.14 Documentation/References

1. A. F. Treshnickov, "The Ice in the Southern Ocean," Proceedings of the Symposium on Pacific-Antarctic Sciences, Eleventh Pacific Science Congress, Tokyo, 1967.
2. J. O. Fletcher, The Heat Budget of the Arctic Basin and Its Relation to Climate, The Rand Corporation, R-444-PR, 1965.
3. --- (ed.), Proceedings of the Symposium on the Arctic Heat Budget and Atmospheric Circulation, The Rand Corporation, RM-5233-NSF, 1966.
4. ---, Ice Extent on the Southern Ocean and Its Relation to World Climate, The Rand Corporation, RM-5793-NSF, 1969.
5. Atlas of the Antarctic, 1966, Vol. 1, Moscow. (Translation in Soviet Geography, May-June 1967, by the American Geographical Society under the title Atlas of Antarctica.)

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION REQUIREMENTS

### 2.1 Time of Year/Season

All times of year required. Highest priority in March and October (minimum and maximum ice extent).

### 2.2 Frequency of Measurement/Observation

Every orbit.

### 2.3 Total Time Span of Measurement/Observation

~ 8 - 12 min./orbit, depending on altitude and inclination and time of year.

### 2.4 Solar Elevation Angle

Not applicable.

### 2.5 Cloudiness

Minimal cloudiness desired for IR and visible wavelength sensors; otherwise, no requirement for clear skies.

### 2.6 Ground Coverage

Variable depending on sensor and scanning mode, from ~ $\pm 10$  -  $\pm 45$  degrees off nadir.

### 2.7 Resolution

For visible photography 100 - 200 ft; for IR and microwave  $< 1$  n. mi.

### 2.8 Accuracy/Precision

Accuracy of location to  $\pm 1$  n. mi.

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Wideband Synthetic Aperture Radar (WBSAR)  
(Wide Coverage, Low Resolution Mode)
- Laser Altimeter/Scatterometer

- IR Multispectral Mechanical Scanner  
(Ocean Surface Temperature Measurement)
  - Passive Multichannel Microwave Radiometer (PMMR)
- b) Correlative Support
- Pointable Identification Camera
  - Data Collection System
- c) Support Equipment
- Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Display
  - Tape Recorders.

## SUMMARY EVALUATION

### M7. ECLIPSE OBSERVATIONS

Definition of observation/measurement requirements evolving from further exploitation of this experimental concept should place this proposed experiment in a Level 1 category for MEO Shuttle sortie missions. As presently conceived, the proposed experiment has many virtues that make it appealing for Shuttle sortie missions, namely:

A program of eclipse observation would not require the initiation of new or special Shuttle sortie missions. Because initial experiments need not be very elaborate, they could be simply instrumented and quickly performed. The integration of an eclipse program into already planned missions would require primarily an examination of proposed orbital inclinations and, to some extent, orbital altitudes. The desirability of obtaining eclipse data can be considered for those missions with flexible orbital or trajectory restraints. The scientific gain could be considerable.

As presently described, this is a Level 2 experiment.

## M7. ECLIPSE OBSERVATIONS

### OBJECTIVE

To perform scientific eclipse experiments in order to obtain information about the earth's atmosphere.

### BACKGROUND AND RELEVANCY

A spacecraft passing through the shadow cones of the earth or the moon will experience a wide variety of phenomena. Eclipses, occultations, and transits involving the sun, earth and moon will be much more frequent than on earth-bound (and often clouded) sites. When one includes the events visible from within the moon's and earth's penumbra, the number and variety of phenomena available for study becomes quite large.

Very little is known about the region of the earth's atmosphere between 70 and 180 km. Yet it is the layers of gas and possible dust at these very altitudes that apparently cause the observed flattening and increased size of the earth's shadow. These layers may also contribute, through refraction and multiple scattering, to the apparent brightness of the eclipsed moon, although a possible relationship between eclipse luminosity and the solar cycle has been long suspected. Although the general role that refraction plays in shadow formation and shadow density have been investigated, the mechanism of refraction and multiple scattering in the earth's atmosphere are not completely understood, and there remains a great need for observational data with which theoretical calculations can be compared.

Terrestrial observations of lunar eclipses present valuable, albeit not too frequent, opportunities to obtain scientifically important information about our atmosphere. Photometric techniques permit investigation of the size and shape of the shadow-cone and an examination of the moon's apparent brightness. Both phenomena are associated with atmospheric conditions--though in a manner not yet totally understood. Our knowledge of these conditions and their effect on the overall structure of the atmosphere is important for understanding the atmospheres not only of earth, but also those of other planets that more and more will be the targets of our nation's space program.

## TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

A Shuttle sortie mission with carefully selected inclination orbiting at sufficient distance above the earth's surface will be in a position to examine a terrestrial event heretofore (prior to manned spaceflight) unavailable for observation: an apparent eclipse of the sun by the earth. As the Shuttle enters the shadow-cone, the astronaut will see a halo of light around the earth, caused by refraction and multiple scattering of sunlight, mixed with the sun's outer corona.

This halo (apparently visible from a very low altitude) will be visible each time the satellite enters the earth's shadow. By selecting proper orbits, scientists will be liberated from waiting for specific eclipse dates. First steps have already been taken, beginning when Project Mercury astronauts observed sunrise and sunset from above the major portion of the earth's atmosphere.

A program of eclipse observation would not require the initiation of new or special Shuttle sortie missions. Because initial experiments need not be very elaborate, they could be simply instrumented and quickly performed. The integration of an eclipse program into already planned missions would require primarily an examination of proposed orbital inclinations and, to some extent, orbital altitudes. The desirability of obtaining eclipse data can be considered for those missions with flexible orbital or trajectory restraints. The scientific gain could be considerable.



## SUMMARY EVALUATION

### M8. OPTICAL PROPERTIES OF CLOUDS

Data gathered by this experiment would help close the gap now existing in the development of the theory of diffuse reflection on systems of realistic clouds. The Shuttle would provide the laboratory and platform for the scientist/astronaut/observer to visually observe cloud bows and glories and record their IR spectrum, and their radiometric and photometric properties for various polarizations.

Experience gained in Shuttle sortie missions might very well lead to a reliable, fully automatic, operational method of distinguishing ice and water clouds and, indirectly, of determining the type and height of the clouds, by noting the intensity, spectrum and radius of the glories at the subsolar point. The instrumentation, telemetry, and other engineering aspects should not be difficult in the light of current space technology.

This experiment rates a Level 2 documentation. When the concepts become more fully defined and the measurement/observation requirements have been detailed, this experiment may be considered for Level 1 for MEO Shuttle Sortie Missions.

## M8. OPTICAL PROPERTIES OF CLOUDS

### OBJECTIVE

To observe optical phenomena produced by sunlight and moonlight on water clouds and ice clouds.

### BACKGROUND AND RELEVANCY

The importance of cloudiness in the atmosphere stems from its relatively high albedo for solar radiation and its central role in the various processes involved in the heat budget of the earth-atmosphere system.

Clouds reflect, absorb, and transmit electromagnetic radiation, but these properties depend very sensitively on the spectral range considered, on the solar zenith angle (for visible radiation), on the cloud parameters such as cloud type, height, and thickness, droplet size and water content, on particulate concentration, and on the nature of the surface below the cloud.

There are a number of natural optical phenomena produced by sunlight falling on water and ice clouds, such as aureoles, coronas, haloes, cloud bows and glories. The first three--aureoles, coronas and haloes--are not observable from above the atmosphere because they are phenomena produced by the passage of sunlight through an optically thin layer of the particles (diffuse transmission). Cloud bows (similar to rainbows) and glories, on the other hand, are phenomena produced by the diffuse reflection of sunlight on the medium, and hence visible from aircraft and satellites when the sun is more or less behind the observer. Both phenomena are the result of light scattering on perfectly spherical transparent (non-absorbing) particles (e.g., liquid water drops, but not ice crystals), which need not be identical in size but must have the same moderate index of refraction. Of the two phenomena, the glory is the more interesting because it appears even on the background of an optically thick cloud, as can be verified by fliers observing the region around the shadow point of their aircraft. The glory appears as a reddish ring with an inner bluish border, with a radius of 2 to 5 degrees of arc, centered around the shadow point, which itself is a bright white area. When the clouds are composed of ice crystals, the glory disappears.

Numerical experiments with the theory of electromagnetic scattering on spherical particles shows that the radius of the glory ring increases as the spheres become smaller with respect to the wavelength. This relative size is one of the main parameters in scattering theory and amounts to considering the same cloud of droplets illuminated by different parts of the solar spectrum.

#### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

Since the theory of diffuse reflection on systems of realistic clouds is not complete, the idea is to use Shuttle as a laboratory. The observer would have at his disposal a near-infrared spectrometer as well as a radiometer supplied with filters and polarizers which he would point and operate manually. He also, of course, has his eyes--a very versatile optical system--and his judgment as a trained observer. As the Shuttle slowly overflies various types of clouds and cloud systems, he would have several alternatives at his disposal. For example, if he observed a glory visually, he would record its infrared spectrum with one instrument and he would scan the glory with the radiometer or photometer, using several filter-polarizer combinations. At the same time he would note and record the visual appearance of the phenomenon and the cloud structure, etc. Since the glory as seen from Shuttle altitude will encompass a much larger cloud field than in the case of aircraft observations, a complete glory ring may seldom be visible unless the cloud field is unusually homogeneous and large.

Several other experimental opportunities may arise. An important one is to seek the infrared glory over a cloud field where the visible glory is absent because of the presence of a top layer of shallow, ice crystal clouds. The use of the polarizing filters is important in all these observations because the peculiar polarization of the glory, mentioned above, is one of its main characteristics.

Experience gained in Shuttle sortie missions might very well lead to a reliable, fully automatic, operational method of distinguishing ice and water clouds, and indirectly of determining the type and height of the clouds, by noting the intensity, spectrum and radius of the glories at the subsolar point. The instrumentation, telemetry, and other engineering aspects should not be difficult in the light of current space technology.

## SUMMARY EVALUATION

### M9. RESEARCH ON HURRICANES AND TROPICAL STORMS

The relevancy of this experiment's objectives rates high, but the requirements for efficient and successful sortie scheduling appear, for the projected time period of application, to be somewhat severe. This limitation may be relaxed or rescinded if such pacing items as increased forecast capability were developed over the next 5 to 10 years. What would be needed would be a high probability of success in pinpointing the location and time of occurrence of storms that would develop into hurricanes. The experiment has virtue in that the Shuttle capability for carrying a large multisensor payload together with man's observational capabilities appear to offer a unique advantage (at least initially) over automated spacecraft.

For the above reasons, this experiment is rated Level 2 for the MEO Shuttle Sortie Missions.

## M9. RESEARCH ON HURRICANES AND TROPICAL STORMS

### OBJECTIVE

To observe and understand the life cycle of hurricanes and other tropical storms.

### BACKGROUND AND RELEVANCY

The hurricane is one of nature's most destructive storms. Hundreds of lives and over a billion dollars were lost in property damage in Hurricane Camille in 1969. In June 1972 Hurricane Agnes caused many billions of dollars of damage throughout the Middle Atlantic States and Northeastern United States. Were it not for the present U. S. hurricane warning service, the loss of life could have reached thousands, as was illustrated by the tragic loss of life in the recent East Pakistan (now Bangladesh) tropical cyclone catastrophe in November 1970.

The typical hurricane has a diameter of 50 to several hundred miles and a lifetime measured in days. It can be detected by satellites and once its existence is known it can be accurately tracked by both satellite and reconnaissance aircraft. They are an international problem, originating and growing to maturity over the oceans of the globe, often far from any weather observing station. In recent years, a wholly new capability to monitor the ocean in order to detect and track these storms has been provided by weather satellites, especially the ATS geosynchronous satellites.

A considerable effort has also been made in recent years to observe and understand the life cycle of a hurricane. To date, however, no observations have been made of the "birth struggles" of these highly destructive storms. It is suspected, for example, that the birth of a hurricane is associated with a natural or spontaneous organization of eddies of lesser size.

### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

During the hurricane or tropical storm season, a trained observer on a Shuttle sortie mission could be constantly on the alert when orbiting over the breeding grounds of these storms. Using the judgement that is peculiarly human, he could select then those events he surmised (or guessed)

were precursors of a hurricane, and based on their nature, choose what sensors to employ for taking data and what observations to make. Later correlation with the actual occurrence of a hurricane would be evidence that what he observed was indeed the precursor he suspected. His task might be only to observe visually and simultaneously report his impressions to the ground, permitting simultaneous observations from or near the earth's surface. In addition, suggestions for additional observations would be forthcoming from the ground, based on analysis of the initial Shuttle observations, the data obtained by the ground observers, or both. It is clear that one cannot predict the occurrence of such an event, nor during the research phase, even fully program (for an automated satellite) the multitude of possible indicators of such events. Man in this case appears to offer a unique advantage over an automated spacecraft. Once what to look for and what is of interest to be measured becomes known, man will lose his uniqueness and an unmanned spacecraft will become a more effective means of accomplishing this task.

## SUMMARY EVALUATION

### M10. COORBITING UNMANNED SATELLITE

Pressure and density information recovered from data to be taken by the proposed experiment are of fundamental importance to an observational program whose objectives are aimed at improving weather forecasting and extending the time range of such forecasts. At present, there seems to be no economical way to obtain these data without using satellites.

This experiment is a logical extension of the stellar refraction and occultation experiment proposed as M2. It offers a greater potential for all-weather day/night observations and offers greater growth possibilities than does experiment M2.

For the present, the proposed experiment is considered for Level 2 for MEO Shuttle sortie missions. As it becomes more fully defined and technologically feasible, it will change to Level 1 consideration; concurrent with this upgrading, experiment M2 would be revised downward from its present Level 1 to Level 2. This is a logical step in the time-phasing of experiments, with M2 receiving higher consideration for early Shuttle sortie missions, while the proposed experiment holds promise for high priority flight assignment on later missions.

## M10. COORBITING UNMANNED SATELLITE

### OBJECTIVE

To test the feasibility of using coorbiting spacecraft to obtain atmospheric pressure and density data.

### BACKGROUND AND RELEVANCY

Most weather prediction models require knowledge of the initial flow and mass distribution (density profile) of the atmosphere, and use primarily the height field of standard pressure surfaces. The customary way to obtain the mass distribution of the atmosphere is to measure, in situ, by radiosonde balloons, or by satellite remote sensing techniques, temperature as a function of pressure and to integrate upward from the surface to obtain pressure as a function of height.

At present, there seems to be no economical way to achieve this global coverage without using satellites. It has been estimated that less than 20 percent of the earth's surface is adequately covered by upper-air observing stations. Numerical forecasts, which treat the earth's atmosphere as a single dynamic system, are prepared routinely for periods of three to four days and for areas covering about one-third of the earth. To extend forecasts to longer periods or to larger areas requires knowledge of the initial state of the atmosphere on a global or at least hemispheric scale. Otherwise, unknown disturbances will migrate into the prediction areas and contaminate the forecast.

Several concepts for the use of coorbiting mother/daughter satellites in the measurement of these parameters have been proposed.

The Stanford concept, advanced by Lusignan, has a satellite configuration consisting of a mother satellite and six daughter satellites, all in the same polar circular orbit. The satellites are spaced so that radio waves from the mother to each daughter pass through the atmosphere, with the path to each succeeding daughter coming closer to the surface of the earth. The path length, as measured by phase and Doppler frequency measurements on each mother-daughter pair, is an indication of the refractivity of the atmosphere along the radio path. Any difference between the straight line separation and the measured radio path length separation, is caused by bending of the radio signal and retardation of the velocity



of transmission of the signal. The refractivity of the atmosphere is proportional to its density and the density along the path is greatest at the point closest to the earth's surface. Thus, the measurement can be considered to be representative of conditions at or near the point of minimum altitude.

This configuration gives measurements at five altitudes on a continuous, periodic, global basis, as the satellites orbit the earth. The link between the mother and closest daughter is used for detection of orbital perturbations and other effects that may produce relative motion between the satellites.

The Raytheon Company technique advanced by Grossi utilizes only two satellites. However, these are in different orbits, and the satellites continuously approach and move away from each other. When the radio path between the satellites passes through the atmosphere, atmospheric refraction measurements may be made in a fashion similar to the Mariner Mars experiment, measuring only the Doppler shift. The reason that absolute path length need not be known is that measurement will begin above the atmosphere, while all measurements using the Stanford technique will be influenced by the atmosphere. The Raytheon configuration provides continuous vertical coverage from the top of the atmosphere to the earth's surface, as opposed to having measurements at a distinct number of levels. During the time when the path is above the atmosphere, ionospheric electron density measurements can be made using the same technique of measuring refraction if a frequency sensitive to ionospheric influences is used. The areal coverage is irregular, depending on the location of the occultations. Several such satellite pairs would be required in an operational system to provide the required density of sample points.

The occultation-refraction techniques face many problems before they can be successfully implemented. To obtain the required accuracy in density and pressure, orbital path accuracies of fifty meters or better are needed. This is slightly pushing the state-of-the art. The multi-satellite technique of Stanford University, in addition, requires a large amount of stationkeeping ability on board each satellite since the relative satellite positions are highly critical. At low altitudes, below about 10 km, water vapor in the atmosphere contributes significantly to the refractivity. Water vapor must be measured to 1 percent to provide accurate density measurements at the 800 mb level. Schemes for measuring the water

vapor have been proposed, but they are still under development and it is unknown whether any will be successful. Multi-path, ducting, and scintillation effects may also prove to be severe problems in the operation of this type of system.

The data inversion technique also requires further study. There is a unique radio path length for each satellite separation and intervening atmosphere combination, but there are many atmospheres that could produce a measured path length. Lusignan and Grossi have each adopted an iterative approach to the problem of deducing the density from phase path measurements. In both cases, a model atmosphere is assumed and the corresponding radio path calculated. The assumptions are based on independent measurements, previous occultation measurements, and general knowledge of the area being measured. The model atmosphere is changed until the calculated path length agrees with the measured path length. Thus, a global vertical density profile is derived.

#### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

The Shuttle sortie mission affords a significant opportunity to test the feasibility of these concepts and to size and resolve those problem areas just described. Conceptually, the Shuttle would eject and place in orbit an unmanned satellite. Stationkeeping and precision tracking and signal monitoring would be accomplished by the on-board astronaut.

It has also been suggested (the 1967 Wood's Hole Summer Study on Useful Applications of Earth-Oriented Vehicles) that coorbiting satellites be configured so that one of the pair carries a source of coherent radiation (visible, IR, microwave). The long path lengths through the atmosphere using this combination would allow accurate sampling of very low concentrations of those gases that are being accumulated in the atmosphere by, for example, man's increased industrial activity. Here, too, combined Shuttle and Shuttle-ejected and controlled coorbiting vehicle would provide the basis for establishing the feasibility of sensor techniques that rely on a precision-coorbiter capability.

## SUMMARY EVALUATION

### M11. SUPERSONIC TRANSPORT UPPER ATMOSPHERIC EFFECTS

This experiment responds to well-documented and high priority needs for early information on the composition and radiative properties of the stratosphere as it now exists, i. e., before it becomes too perturbed by increasing numbers of stratospheric SST flights. This information is required in order to assess the possible effects that a commercial fleet of SSTs would have on the environment by inadvertently modifying the upper atmospheric composition and radiative properties. The information would provide for more realistic mathematical models of the upper atmosphere which would then be used to simulate the SST effects.

The importance and timeliness of this problem is commensurate with the Shuttle's capability for obtaining the baseline information required. Man's role would probably be minimal. Given the present state of experiment definition, this experiment qualifies for Level 2 consideration for MEO Shuttle Sortie Missions.

## M11. SUPERSONIC TRANSPORT UPPER ATMOSPHERIC EFFECTS

### OBJECTIVE

To obtain baseline information on the composition and radiative properties of the stratosphere as it now exists, i. e. , before it becomes too perturbed by increasing numbers of stratospheric flights.

### BACKGROUND AND RELEVANCY

Among the reasons for increased meteorological interest in the upper atmosphere is the recent and continuing concern for possible environmental hazards (e. g. , changes in global weather and climate and radiation, and increased air pollution) associated with large scale supersonic transport operations.

A number of valuable reports appearing over the past few years have attempted to assess the effects of a commercial fleet of SST's on the environment. Ranging from cautiously optimistic to alarming, they have not been truly conclusive, primarily because of a lack of necessary and sufficient baseline information.

Theoretical and applied research programs will have to be initiated to determine what the long-term impact of SST engine exhaust products would be with regard to modifying and/or changing the physical, chemical, and radiative properties of the stratosphere.

The chief reason that so much attention has been recently focused on the environmental pollution aspects of the SST is that they have cruise altitudes in the lower stratosphere--a region with properties importantly different than the troposphere, where existing commercial jet aircraft fly.

Because the stratosphere is dynamically more stable than the troposphere (temperature increases with height from the tropopause to the stratopause near 50 km), pollutants deposited in the stratosphere may remain there for periods of a few months to several years, depending on the season and location of deposition. In contrast, pollutants deposited in the troposphere can be expected to remain for much shorter periods of time--on the order of days to weeks. Thus, the long residence times associated with the stratosphere could lead to a gradual accumulation of

pollutants. In some cases these could reach global average concentrations corresponding to currently existing concentrations.

For the purpose of appreciating the environmental problems of a commercial SST fleet, assume a fleet size as originally anticipated before the cancellation of the Boeing 2707 program. By the year 1990, 600 SST's including those of foreign manufacture, were predicted. Given five flights a day, each plane would consume (on the average) 66,000 kg of fuel per flight. With the assumption of today's fuels, such a commercial fleet would, over a two-year period, deposit\* in the stratosphere the following:

$4.6 \times 10^{11}$  kg of  $\text{CO}_2$ ,  $1.9 \times 10^{11}$  kg of  $\text{H}_2\text{O}$ , plus an estimated\*  $10^9$  kg of  $\text{NO}_x$ ,  $2.8 \times 10^8$  kg of CO,  $3 \times 10^7$  kg of unburned hydrocarbons,  $3 \times 10^7$  kg of  $\text{SO}_2$ , and  $3 \times 10^6$  kg of soot.

The dynamical stability of the stratosphere is tied to the increase in chemical activity occurring there. Ozone, for example, absorbs solar ultraviolet radiation, decomposing into  $\text{O}_2$  and O, which in turn recombines to form  $\text{O}_3$  with a subsequent release of energy in the form of heat. This cycle of photolysis followed by recombination has the net effect of converting ultraviolet energy light into heat. In this way much of the potentially damaging UV radiation is prevented from reaching the surface of the earth. The heat released produces the characteristic stratospheric increase in temperature with height which is primarily responsible for the dynamical stability of this region.

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\* While the amounts of major products of jet engine exhaust ( $\text{CO}_2$ , and  $\text{H}_2\text{O}$ ) are well known, there is much variability in the reported quantities of  $\text{NO}_x$ , CO, unburned hydrocarbons,  $\text{SO}_2$ , and soot emitted from a jet exhaust. Measurements on the composition of exhausts during actual or simulated stratospheric flight appear to be nonexistent. Rather, values provided by aircraft engine manufacturers are based on extrapolations of measurements made under non-stratospheric cruise conditions. Thus, it is not now known whether these exhaust composition predictions are indeed acceptable. Too, both fuel composition and engines designed for use in 1990 will be different than they are now.

With the accumulation of additional water vapor and oxides of nitrogen in the stratosphere, the ozone cycle could be influenced in two ways: first, by chemical chain reactions which have the effect of catalyzing the destruction of odd oxygen ( $O_3$  and/or  $O$ ). With the diminution of  $O_3$ , there would be subsequent changes (increases) in the intensity of the damaging ultraviolet light arriving at the surface of the earth. Secondly, with lesser amounts of  $O_3$  available for the conversion of ultraviolet light into heat, the dynamic stability of the stratosphere would be changed, becoming less stable.

It has also been suggested that soot particles and aerosols (which may result from  $SO_2$  and  $NO_x$ ) might conceivably reach levels commensurate with those remaining in the stratosphere several years after a large volcanic eruption. These particulates scatter sunlight, and some thinking has it that this could cause a noticeable change in the temperature of the earth's surface.

Specific information needs relate to the spatial and temporal distribution of effluents in the stratosphere and changes in the ozone distribution. In order to determine the effect that additional  $H_2O$  and  $NO_x$  will have on the distribution of  $O_3$ , information is needed on, e.g., the following:

- The stratospheric distribution and concentration of  $H_2O$  and  $NO_x$
- The rate constants and quantum yields of all reactions involving  $H_2O$  and  $NO_x$
- The relative efficiency of natural sources and sinks
- The importance of atmospheric dynamics in influencing the chemistry of the stratosphere.

Very few measurements of  $H_2O$  concentrations have been made in the stratosphere; of these, concentrations ranged from 5 to 30 ppm, and some seasonal variations have been noted. However, the overall accuracy of these measurements has not been assessed.

There is a paucity of information on the stratospheric distribution of the oxides of nitrogen. Estimates currently put these concentrations in the range of 1 to 10 ppb--values which tax the state-of-the-art of

measurement techniques. It is generally agreed that since chemical equilibrium between  $\text{NO}_2$  and  $\text{NO}$  is reached rapidly, measurement of one or the other would suffice; yet, the measurement of such small quantities (i.e.,  $10^9$  to  $10^{10}$  molecules/cc) remains extremely difficult. As the capability for measuring  $\text{H}_2\text{O}$  and  $\text{NO}_2$  and/or  $\text{NO}$  develops, simultaneous measurements to include  $\text{O}_3$ , temperature, and the solar spectrum as a function of altitude will be required in order to establish information regarding diurnal, seasonal and latitudinal variations.

Information must be developed which permits the identification of sources and sinks of trace constituents in the stratosphere. A small concentration of a particular constituent may indicate the lack of an effective source for it, or the existence of a particularly effective means for its removal. Sources and sinks may be either dynamical in nature, with substances being transported into or out of the stratosphere, or chemical. It has been suggested, for example, that thunderstorms that penetrate the stratosphere are an important source of water vapor. If this is the case, then the low concentration of water vapor found in the stratosphere would indicate an equally effective sink mechanism.

The implication that the foregoing discussion on the effects of inadvertent modification of the upper atmosphere has to an SST upper atmospheric effects experiment for a Shuttle sortie mission should be apparent. What has been indicated is that a meaningful assessment of the environmental factors associated with the SST's will require a much better knowledge of the composition and radiative properties of the stratosphere as it now exists, i.e., before it becomes too perturbed by increasing numbers of stratospheric flights. Early monitoring the four-dimensional distributions of water vapor, ozone, oxides of nitrogen, and the ultraviolet spectrum will provide such meaningful information.

#### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

A complement of experimental and operational sensors would measure the spatial and temporal distributions and concentrations of stratospheric  $\text{H}_2\text{O}$ ,  $\text{NO}_x$ ,  $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{O}_3$  and other trace constituents. In addition (and concurrently), the 3-dimensional thermal and dynamic structure of the stratosphere would be determined as a function of time.

Particular emphasis for data acquisition would be given to specific regions (e. g., the North Atlantic and North Pacific) which correspond to flight routes having potentially high SST traffic.

Man's role would be minimal, consisting of sensor warm-up, checkout, monitoring, calibration and possibly modification.



## SUMMARY EVALUATION

### M12. DETAILED HIGH RESOLUTION STEREO CLOUD PHOTOGRAPHY

Stereo cloud photography holds much merit for obtaining useful information not easily obtainable by other means. None of the present or planned satellite data acquisition systems have been or will be designed to exploit stereoscopic information. The proposed experiment is easy to implement; both stereoscopic acquisition and stereoscopic viewing criteria can be easily met, with no particular difficulty. Man's role is simple, but a necessary one, since targets would be mostly those of opportunity.

This experiment, when fully defined, should be suited for Level 1 consideration in early MEO Shuttle sortie missions. Its definition status at this time puts it in Level 2.

## M12. DETAILED HIGH RESOLUTION STEREO CLOUD PHOTOGRAPHY

### OBJECTIVE

To obtain a selected, but large number, of stereographic quality cloud photography for stereoscopic viewing, interpretation and analysis.

### BACKGROUND AND RELEVANCY

For a number of reasons stereo interpretations of cloud pictures obtained from satellites have not been successful in the past. Belatedly, it was found that the Nimbus II APT pictures, when properly processed, provide excellent stereoscopic viewing.

There can be no question that stereoscopic viewing and investigation of meteorological satellite photography can provide considerably more information than a monocular or single image study of the area photographed.

Photo-geologists, photo-foresters, military photo interpreters, and photogrammetrists, have long since proven that a three-dimensional study of vertical and high oblique aerial photography can provide them with added recognition of feature relationships as well as provide a means of height discrimination and height measurement. For the meteorologist, it provides a means of determining absolute and relative cloud heights; it provides information on slopes and shapes of cloud formations; it can be used to discriminate cloud features from ground features exhibiting the same tonal characteristics; it can be used for the determination of cloud direction and speed. It can be used for the study of cloud dispersion and feature change provided that enough "fixed" surrounding information is available for correct stereo correlation of the two images. It can be used for the determination of cloud direction and speed when the cloud shadows are viewed on land of known height. In the case of satellite photography, the stereo technique visually illustrates the perspective view of high oblique imaging angles and the effect of earth curvature, both of which might otherwise lead to incorrect interpretation, measurement, and location of cloud formations.

The meteorologist has, in many cases, recognized the value of stereo techniques and has employed them in evaluating terrestrial and aerial photographs of meteorological phenomena, but until recently the taking conditions and types of satellite cloud photographs did not suitably lend themselves to this type of analysis.

Unfortunately, none of the present and planned satellite acquisition systems has been designed to exploit stereoscopic information, and in the systems where stereo study is possible, the graphic record normally provided to the meteorologist is not suited to good viewing.

#### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

As a Shuttle sortie experiment, both stereoscopic acquisition and viewing criteria can be easily met, with no particular difficulty. The sensor payload would consist of two cameras, capable of providing horizontal resolutions of the order of 100 ft. They would be nadir-pointed, and positioned to provide the stereo baseline. Targets would be mostly those of opportunity and the primary role of man would be to locate and select targets for acquisition of stereo photography.

## SUMMARY EVALUATION

### M13. METEOR WINDS BY RADAR AND BY OPTICAL OBSERVATION

This experiment addresses an important information need; i. e., winds in the upper atmosphere. No other experimental concept exists for routinely obtaining winds on a global or near-global basis. The feasibility of the suggested approach has not been demonstrated and radar system sensitivities have not been analyzed. For these reasons, this experiment is relegated to a Level 3 for MEO Shuttle sortie missions. If further investigation of the concept proves encouraging, the experiment may be considered appropriate for Shuttle sortie missions in the mid-to-late 1980s; otherwise, it should be removed from the selected list of experiments.

### M13. METEOR WINDS BY RADAR AND BY OPTICAL OBSERVATION

Upper atmosphere meteorology is concerned with the observation, description, explanation and prediction of dynamic, thermodynamic and radiative properties, processes and effects in the regions lying above about 10 - 20 km. An important parameter that must be measured or derived is the wind field which addresses problems relating to the circulation of the upper atmosphere.

Observation of persistent ionized meteor trails (trains) have been observed for many years by ground-based radars and have yielded derivations of winds between ~80 - 100 km. Since at any one place on the ground several hundred meteors/hour appear to be available, the experiment aims at using a Shuttle-borne radar for observing persistent meteor trains in order to derive wind velocities in the upper atmosphere.



## SUMMARY EVALUATION

### AFRI. INTERNATIONAL AGRICULTURAL EXPERIMENT STATION MONITORING PROGRAM

Agricultural experiment stations around the world often perform a similar variety of tasks which relate to the agriculture-sector. These tasks might be performed more effectively if remote sensing data were routinely available which presented agricultural data for many different locations in a common format. Such common format data could permit crop damage assessment and evaluation of the success of various types of crops under various levels of stress. The uniform format data would also assist in intercomparisons among various stations and provide data which might be usefully applied to training programs. A further extension of this concept of a uniform data base would be an annual meeting of Agricultural Experiment Station directors where the unifying theme would be the Shuttle (MEO) data and associated analyses.

This is a valuable experiment and is rated Shuttle MEO Acceptable - Level 1.

## AFR1. INTERNATIONAL AGRICULTURAL EXPERIMENT STATION MONITORING PROGRAM

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas

- Crop inventory (area planted and yield)
- Crop vigor determination
- Monitor soil conservation practices
- Evaluation of pasture conditions.

#### 1.2 Experiment Objectives

- To provide agricultural experiment stations around the world with a variety of remote sensing data for improving their research and farm advisory functions
- To provide improved means for performing crop inventory (acres planted, yield prediction, etc.) and assessing crop vigor (insect and pathogen influence, drought impact, wind and flood damage, etc.)
- To assess the state of soil condition (drought, salinity, toxicity, etc.) and soil conservation practices (erosion control, fertilization, irrigation methods)
- To evaluate pasture condition and assess pasture improvement programs.

#### 1.3 Experiment Background

Agricultural experiment stations around the world often perform a similar variety of tasks which relate to the agricultural sector. These tasks could be performed, more effectively in many cases, if a variety of remote sensing data were available for use by these stations. Timely data for specified areas would help to assess the success of treatments, extent of damage, and size of crop yields expected, for example. With standard format remote sensing data available on short notice, and adequate training for personnel who will analyze the data, experiment stations should be able to provide better service to their agricultural communities. The uniform coverage provided would assist in transfer of data and technology between various stations. For example, evaluations of data acquired might be usefully part of an annual meeting of various agricultural station directors.



#### 1.4 Proposed Technical Approach

- Collect multispectral imaged data from Shuttle (MEO)
- Establish a center for data acquisition planning, and develop a rapid means for receiving requests for data, rating them, and planning missions
- For each specific geographic area, make the imaged data available as soon as possible to the appropriate station.

#### 1.5 Relevancy of Experiment

- Crop area and yield
- Crop vigor and condition
- Soil characteristics and condition.

#### 1.6 Role of Man

- Coordinate acquisition of data on Shuttle, making adjustments and changes as conditions vary
- Perform onboard analysis if necessary
- Perform analysis in earth laboratories.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

Use of tracking telescope for off-axis high resolution photography.

#### 1.8 Supporting Research and Technology Required

- Development of high resolution multispectral scanners
- Establishment of critical times for monitoring crop types and diseases not presently under investigation
- Establishment of experiments in crop management which lend themselves to remote sensing procedures
- Establishment of exact geographic coordinates for sites.

#### 1.9 Targets

As requested by experiment stations, will probably consist of rather small areas (or sample areas if large regions are being assessed) near experiment station sites.

#### 1.10 Truth Sites

Agricultural experiment station fields and cooperating adjacent farm-field experiments.

#### 1.11 Orbital Parameters

100 - 200 n. mi. ; any inclination. Virtually any shuttle mission will cover some sites. A catalog of sites should be available for inclusion, at appropriate times for both prime and add-on experiments.

#### 1.12 Data Required by Investigator

- Digital tapes from multispectral scanners
- 70 mm or 9 x 9 inch multiband and color + color IR photography
- SAR multifrequency images and/or digital tapes.

#### 1.13 Principal Users

Staffs of agricultural experiment stations.

#### 1.14 Documentation/References

Annual Reports of Laboratory for Agricultural Remote Sensing (LARS) at Purdue University, Weslaco Agricultural Experiment Station, Texas, North Dakota, etc.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Individual experiment stations will supply their own schedules with desired and acceptable dates for missions. On any given Shuttle mission some stations will have suitable experiments in operation. Poleward of latitude 30 degrees, most missions will be desired at monthly intervals from March to September (Northern Hemisphere) and September to February (Southern Hemisphere). Equatorward of latitude 30 degrees, missions are likely to be requested in any month.

### 2.2 Frequency of Measurement Observation

As requested. Will vary from monthly to only once or twice during a cropping season.

### 2.3 Total Time Span of Measurement/Observation

On a single Shuttle mission, the observation time over a single agricultural experiment station will be a few seconds with the tracking telescope, plus necessary set-up, acquisition and hold time. Probably one minute per station.

### 2.4 Solar Elevation Angle

Normally >30 degrees; immaterial if active radar is used.

### 2.5 Cloudiness

Less than 10 percent for optical sensors; immaterial if imaging radar is the primary sensor.

### 2.6 Ground Coverage

Most Agricultural Experiment Stations and adjacent cooperating farm-field experiments would occupy compact areas of less than 1000 hectares. The great majority will be less than 200 hectares.

### 2.7 Resolution

- Photographic systems 5 to 30 meters
- Multispectral scanners 30 meters or better if feasible
- Imaging radar 15 meters.

## 2.8 Accuracy/Precision

300 meters positional accuracy.

## 2.9 Shuttle Instrumentation/Equipment Requirements

### a) Primary Instruments

- ● Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
- Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
- High Resolution Wideband Multispectral Scanner  
(20 Spectral Bands)
- Multifrequency Wideband Synthetic Aperture Radar  
(Narrow Coverage, High Resolution Mode)

### b) Correlative Support

- Pointable Identification Camera

### c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Display
- Tape Recorders.

## SUMMARY EVALUATION

### AFR2. MULTISTAGE SAMPLING OF VEGETATION RESOURCES

One of the most valuable roles for space acquired remotely sensed data lies in its use in multistage sampling of various resources. With this technique successively closer, higher resolution looks at smaller sections of the landscape are utilized within a statistical sampling rationale to obtain accurate estimates of various resource parameters. Shuttle-borne sensors can provide a unique input of both the large over-view low-resolution observation and statistical samples within that over-view with higher resolution sensors. Man can assist the sampling routine to achieve optional initial stratification and thereby reduce the overall sampling error.

The experiment can be applied to renewable as well as non-renewable resources. It is an important aspect to be achieved from Shuttle. The overall rating for Shuttle (MEO) is Acceptable - Level 1.

## AFR2. MULTISTAGE SAMPLING OF VEGETATION RESOURCES

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas

- Vegetation resource sampling and inventory
- Yield predictions.

#### 1.2 Experiment Objectives

- Provide updated vegetation resource type maps
- Produce accurate estimates of standing crop (range, agriculture and forestry)
- Assess role of Shuttle in improving inventory data now collected by conventional techniques, and as collected by ERTS and aircraft or Skylab and aircraft program
- Test feasibility of operational sampling concepts arising from experiments with the Earth Terrain camera on Skylab
- Develop systematic operational procedures for later Shuttle missions
- Develop procedures for supplementing ERTS type operational data either by follow-the-leader or time delayed Shuttle missions.

#### 1.3 Experiment Background

One of the most valuable roles for space-acquired remote sensing data lies in its use of multistage sampling of earth resources. With this technique, closer higher-resolution looks at successively smaller portions of the landscape are taken. A very limited number of ground measurements are made and then expanded through the appropriate sampling formulas to derive estimates of resource parameters.

P. G. Langley has already indicated how a low resolution Apollo 9 space photograph can be used to select the primary sample units and markedly reduce sampling error in the process. In this case, aerial photography at three scales and ground measurements were used to conduct a forest inventory of 10 million acres of land in the Mississippi Valley.

Improvements in the technique are expected with the quick response time, scheduling flexibility, and high resolution capabilities of Shuttle.

A particularly attractive feature of Shuttle is the possibility of embedding high resolutions systematically at .5 log resolution steps in the coarse resolution images (resolutions of 5 meters, 10 meters, 30 meters and 100 meters) and thereby reducing, if not eliminating, aircraft use in remote or difficult-of-access areas.

Multistage sampling with Shuttle offers many other systems through use of different sun angles or a single mission.

#### 1.4 Proposed Technical Approach

Use the flexibility of a variety of Shuttle flight dates to select the optimum and often critical time(s) of year to discriminate important vegetation types.

- Obtain moderate resolution remote sensing data (rely on radar, MSS, or photography depending on cloud cover characteristics and 1980 state-of-the-art advances) of study areas
- Select primary sample units:
  - a) Onboard automatic analysis of moderate resolution data or imagery if feasible
  - b) Return film or data to ground for analysis
- Obtain higher resolution imagery of subsample areas on same Shuttle mission if alternative (a) used, or on next mission if (b) used. Number of sample stages dependent upon allowable sampling error, resolution required to derive resource parameters, etc.
- Obtain a limited number of ground observations within the areas selected as the last stage of the sampling procedure
- Expand measurements of resource parameters through sampling formulas to obtain desired estimates.

Use Shuttle to determine its role in improving the information extraction process as developed with ERTS and Skylab.

### 1.5 Relevancy of Experiment

- Vegetation map information
- Statistics on extent and quantity of important vegetation types (forest types, crop types, etc.).
- Major contribution to management programs of the 1980s dealing with renewable resources
- For undeveloping countries offers a significant opportunity to leap-frog directly to the most advanced techniques in resource evaluation and monitoring.

### 1.6 Role of Man

If onboard processing of synoptic remote sensing data is undertaken, man's role will be to review results and implement subsampling programs and to select those subsample areas which are cloud-free at time of overflight. In missions with repeat over a given site as much as 15 to 20 minutes may be spent by investigators selecting future subsampling sites.

### 1.7 Impact of Experiment on Shuttle Sortie Mission

Will require use of high resolution tracking telescope for highest resolution samples. Initially much of the work with the telescope will be manual. As operational procedures are formalized in successive missions, pre-programming of high resolution sensors for automatic acquisition, hold and photography should be envisaged as much as feasible. In missions with several repeats over a site during a 5 to 7 day mission, off-axis sites selected for high resolution sampling by an investigator can be programmed onboard by the Shuttle investigator, or on the ground (based on earlier missions). Software to program a maximum sampling will need to be developed for automatic acquisition.

### 1.8 Supporting Research and Technology Required

Further investigations of:

- Sampling procedures — tradeoff in information derived from each stage and resolution of imagery used at each stage
- Role of each sensor type (SAR, MSS, cameras) in sample design — all weather, day-night capability.



SAR capability might override its lower resolution to provide more information than via other systems (value of ground data is reduced if some areas are cloudy while photography is obtained; all ground data is usable if SAR imagery is acquired).

Development of multi-frequency, multi-polarization, multi-resolution radar.

### 1.9 Targets

Specified by particular resource problems. Examples for the purposes of developing Shuttle reference missions are as follows:

#### U. S. A.

- Mississippi Valley (Bootheel of Missouri)
- Central Valley of California
- Yellowstone National Park

#### OVERSEAS

- Lower Cape York Peninsula, Queensland Australia, near Georgetown
- Central Highlands of New Guinea near Watabung
- Allejuela Province, Costa Rica, near Quesada
- Cordillera Central, Puerto Rico
- Serra dos Carajas area, State of Para, Brazil
- Gabon, near Lambarene
- Northern region of Nigeria, near Kano
- Between Tehran and the Caspian Sea, Iran
- Northern Celebes, Indonesia, near Menaco

Specific targets within these areas will be selected as part of the multi-stage sampling procedure--a continuing process as data and images are received and processed.

#### 1.10 Truth Sites

Selected as final stage in sampling procedure. Number of sites depends on sampling error allowed, variation of parameters being measured, etc.

#### 1.11 Orbital Parameters

To be determined for particular locations.

Suggested locations in U. S. A. :

- Mississippi Valley (Bootheel of Missouri)
- Central Valley of California
- Yellowstone National Park.

Example: Orbit - 50 degree inclination  
Altitude - 100 - 200 n. mi.  
One look per mission.

#### 1.12 Data Required by Investigator

- Analysis of synoptic imager---either automated, on-board analysis, or manual interpretation on ground
- Subsample imagery (for automated or manual analysis)
- Field data.

#### 1.13 Principal Users

Resource management agencies which carry out inventories of wildland vegetation (forests, rangelands, etc.) or agricultural cropland.

#### 1.14 Documentation/References

P. G. Langley, 1971. "Multistage Sampling of Earth Resources with Aerial and Space Photography," Monitoring Earth Resources from Aircraft and Spacecraft, R. N. Colwell, et al. NASA SP-275. 170 pp.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Depends on phenology or development of plant types. A specific catalog will need to be developed by investigators either as crop time line events or natural plant community phenologies. For reference missions, particular selected cases will be worked out in detail.

### 2.2 Frequency of Measurement/Observation

Dependent upon information needs--yearly or less often for forestry, perhaps quarterly for agriculture.

### 2.3 Total Time Span of Measurement/Observation

Will vary from case to case. For planning reference missions the following may be used per site:

Time of observation over target	30 seconds
Time in preparation for target	5 seconds
Time in selection of additional sub-sample areas for repeat coverage	5 minutes

### 2.4 Solar Elevation Angle

>35 degrees, except where radar is the principal instrument.

### 2.5 Cloudiness

Not critical for stage(s) in which radar is employed; 10 - 20 percent maximum for other sensors.

### 2.6 Ground Coverage

Synoptic coverage of entire area in which resource(s) being inventoried occur; swath width to be imaged to be determined by size of area. High resolution subsamples as determined in sample design.

### 2.7 Resolution

100 meters and 30 meters for synoptic look; 10 meters and 5 meters for finer resolution samples for detailed analysis and better if possible.

## 2.8 Accuracy/Precision

Pointing accuracy - 200 meters.

Resolutions for particular sensors:

SLAR	15 meters
MSS	30 meters
Cameras	100 meters
	30 meters
	10 meters
	5 meters (or better if feasible).

## 2.9 Shuttle Instrumentation/Equipment Requirements

### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
- Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
- High Resolution Wideband Multispectral Scanner  
(20 Spectral Bands)
- Multifrequency Wideband Synthetic Aperture Radar  
(Narrow Coverage, High Resolution Mode)

### b) Correlative Support

- Pointable Identification Camera

### c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Display
- Tape Recorders.

## SUMMARY EVALUATION

### AFR3. WILDLIFE - ECOSYSTEM STUDIES

The principal objective of this experiment is to determine the grazing locales, habitat, and environmental conditions of major grazing wildlife species. Three principal areas are involved, the Northwestern U.S.A, Arctic Alaska and Equatorial latitudes in Africa. A major problem in wildlife management and control is the very inadequate knowledge of the spatial movements of wildlife at particular times in their life cycle, at particular seasons, and under varying degrees of environmental stress and hazard. These motions and stresses to be fully understood need to be interpreted against a background of the environment in terms of availability of shade, forage and presence or absence of critical environmental conditions of temperature and related parameters.

The design followed in this experiment is of "total" instrumentation to follow animals, and their physiological reactions in space and time. The experiment will require micro-miniaturization and development of very low weight packages for use on all but the very largest of grazing animals. The combination of utilizing fully instrumented packages on the animals monitoring the animals' condition and also its local environment, together with high resolution photography from Shuttle, make this a unique experiment in scientific studies of wildlife. The Shuttle (MEO) rating is Acceptable - Level 1.

### AFR3. WILDLIFE - ECOSYSTEM STUDIES

#### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

##### 1.1 Associated Problem Areas

- Grazing wildlife and ecosystem studies
- Commercial (tropical) grazing studies.

(Related Areas: Nomadic Herding)

##### 1.2 Experiment Objectives

To determine grazing locales, habitat and environmental conditions of major grazing wildlife species. Three principal areas are involved-- Northwestern U.S.A., Arctic and Equatorial (Africa) latitudes.

##### 1.3 Experiment Background

A major problem in wildlife management and control is the very inadequate knowledge of the spatial movements of wildlife at particular times in their life cycle, at particular seasons, and under varying degrees of environmental stress and hazard. These motions and stresses to be fully understood need to be interpreted against a background of the environment in terms of availability of shade, forage and presence or absence of critical environmental conditions of temperature and related parameters.

The present proposed study being one of studying wildlife in its environmental context, requires repetitive coverage over time, both short and long terms. Short-time changes can most readily be studied, for particular animals in equatorial orbit, where 110 minute repeat observations are feasible. Longer time studies will be acceptable (that is, all one can obtain, realistically) in higher latitude orbits.

The design followed in this experiment is of "total" instrumentation to follow animals, and to monitor their physiological reactions in space and time.

##### 1.4 Proposed Technical Approach

There are seven parts to the proposed approach, each requiring development of specialized miniaturized electronic contact and sensing equipment.

- 1) Instrumentation of grazing wildlife (or commercial stock) to obtain data on the animal's physiologic condition under various environmental stresses.
- 2) Instrumentation of the animals to determine environmental conditions (net radiation load, ground temperature, relative humidity, etc.)
- 3) Instrumentation to transmit this data coded for the animal, and with suitable latitude and longitude reference to Shuttle.
- 4) Instrumentation to receive satellite navigation data, to retransmit to Shuttle for computer processing to establish geographic coordinates.
- 5) Medium resolution cameras to observe the environment.
- 6) Tracking telescope for high resolution photography of the exact locale on successive passes.
- 7) Thermal IR Scanner for repeat mapping of thermal characteristics of the grazing area.

In equatorial latitudes an equatorial orbit over East Africa (Serengeti Plains, etc.) would bring many animals readily into repetitive coverage at about 100 - 110 minute passes. Thus, detailed animal cycle studies could be completed readily.

In Arctic latitudes repeated observation would be available in Alaska with a 67 degree inclination orbit.

In Northwest U. S. A. the spring Equinox will be a critical time of calving, just prior to leaf-out. Thus, animals may be monitored in deciduous forest areas.

#### 1.5 Relevancy of Experiment

Environmental/spatial/ecological and related parameters in relation to wildlife grazing and movements.

#### 1.6 Role of Man

Use of tracking camera slaved to coordinate location from wildlife.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

Equatorial orbit--would require special mission; 67 degree inclination orbit would serve both Alaska and Pacific Northwest.

### 1.8 Supporting Research and Technology Required

Development of instruments, lightweight, and reliable for:

- 1) Instrumenting animal physiology
- 2) Instrumenting animal to determine local environmental conditions
- 3) Development of lightweight system for determining animal latitude and longitude. Improved Doppler systems will be needed.

### 1.9 Targets

Actual location of animals.

### 1.10 Truth Sites

Equatorial orbits: Serengeti Plains

Northwest U. S. A.: Same as snow experiment in Oregon

Alaska: Various, close to 67 degrees N.

### 1.11 Orbital Parameters

- 1) Equatorial orbit — Case I
  - 2) 67 degree inclination (or polar) — Case II
- Altitude — 150 n. mi.

### 1.12 Data Required by Investigator



1.13 Principal Users

- Wildlife managers
- Department of Interior
- International Wildlife Federation
- Ecologists, museums
- International and foreign agencies.

1.14 Documentation/References

1. R. F. Pascucci, N. A. Liskov and L. E. Garvin (1972), "The Potential Application of Space Technology to the Radio Tracking and Biotelemetry of Unrestrained animals," In Remote Sensing of Earth Resources, Vol. I, F. Shahrokhi, Editor, University of Tennessee, Tulaoma, Tennessee, pp. 219-247.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/ REQUIREMENTS

### 2.1 Time of Year/Season

Polar orbit — late March; equatorial orbit — initially late March. With the feasibility established in the first experiment, it should then be expected that round-the-year and round-the-clock requests will be made for monitoring wildlife. Operational planning will then be required.

### 2.2 Frequency of Measurement/Observation

- Equatorial orbit — each orbit if necessary
- Polar orbit — day and night, once/mission.

### 2.3 Total Time Span of Measurement/Observation

Two minutes

### 2.4 Solar Elevation Angle

>30 degrees if feasible; >20 degrees acceptable.

### 2.5 Cloudiness

NIL — 5 percent if scattered; 60 percent solid.

### 2.6 Ground Coverage

Same as wide area camera, approximately 80 x 80 n. mi.

### 2.7 Resolution

Cameras: 1) 5 meters  
2) 30 meters

### 2.8 Accuracy/Precision

300 meters pointing. This requirement may also apply to the Doppler measurements for location of the animals.

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)

- Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
  - High Resolution Wideband Multispectral Scanner  
(20 spectral bands)
  - Data Collection System
- b) Correlative Support
- Pointable Identification Camera
- c) Support Equipment
- Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Displays
  - Tape Recorders.

## SUMMARY EVALUATION

### AFR4. WINTER DAMAGE ASSESSMENT IN FORESTLAND

The principal objective of this experiment is to establish whether extensive and especially meso-scale winter kill in major forest areas can be detected and quantified as to its severity and spatial extent in mountainous forest reserves. There are many factors related to severe weather which produce both patchy and extensive winter kill, or limb damage in forests. The widespread but discontinuous destruction makes monitoring such events exceedingly difficult. Rapid knowledge of winter kill is important in enabling timber to be salvaged and clean-up operations to be carried out to reduce fire hazard and establish new plantings. It is also important in monitoring areas of possible disease and insect spread. Man's role in selecting targets would be important with a five meter resolution camera system with narrow fields of view which may be used in the areas of previous detection with coarse resolution systems, or for rapid coverage of areas where general climatic statistics indicate the possibility of severe damage. The Shuttle (MEO) rating is Acceptable - Level 1.

## AFR4. WINTER DAMAGE ASSESSMENT IN FORESTLAND

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Area

Forest resource use.

#### 1.2 Experiment Objectives

The principal objective of this experiment is to establish whether extensive and especially meso-scale winter kill in major forest areas can be detected and quantified as to its severity and spatial extent in mountainous forest reserves.

#### 1.3 Experiment Background

There are many factors related to severe weather which produce both patchy and extensive winter kill, or limb damage in forests. The widespread but discontinuous destruction makes monitoring such events exceedingly difficult. Rapid knowledge of winter kill is important in enabling timber to be salvaged and clean-up operations to be carried out to reduce fire hazard and establish new plantings.

Extensive limb breakage, falling short of winter kill, and induced principally by ice storms or wet snow prior to leaf-fall in deciduous species is also very important and may also be either continuous or patchy in distribution. A major occurrence in North Carolina in the late 1960s involved 10 counties. It is highly desirable to remove broken limbs, stripped limbs and severely damaged trees to reduce infection points for later fungal and insect attack. At the very least, a knowledge of the location of such damaged forest enables later and better monitoring for possible disease and insect spread.

In mountainous terrain, the differences in temperature conditions with changes in altitude can change storms from rain to ice to snow over relatively short distances, thus making for patchiness in the extent of hazard to trees. In addition, unseasonal warm weather in mid-winter can set up severe transpiration needs in evergreen species. Not uncommonly, the "Red Belts" so produced (named because the trees turn red and tend to occur in belts) occur in mid-slope along a ridge, may be 1000 ft wide, and stretch for 10 miles or so.

With throw from violent squall lines, as well as disastrous wind throw from late-season hurricanes, in many instances may not be fully detected until the Spring leaf-out. Finally, there remain snow avalanches which destroy substantial acreages of timber.

The rid of weather-reporting stations in mountainous areas is quite inadequate to establish the degree of such occurrences, although each year conditions broadly conducive to widespread or patchy kill do occur and are known from the general weather record.

To summarize, it is desirable to know the location of damaged areas in more detail and with higher resolution sensors than ERTS-type unmanned systems will provide.

#### 1.4 Proposed Technical Approach

In the areas of the mixed deciduous and evergreen forests in Eastern U. S., it is proposed that the following procedure be followed:

- 1) Beginning in early-Fall, the general weather conditions be monitored in a series of stations and locations where severe weather (excessive cold early in the season, excessive ice and snow fall, spells of unseasonally warm weather in mid-Winter) and damage are likely on general topographic and meteorological grounds. These areas should be recorded, plotted on base maps as areas for detailed scrutiny from spacecraft in the Spring.
- 2) Beginning at about the equinox or early-April in the Southern Appalachians and extending through to late-May - mid-June in the Northern Appalachians, variations in leaf-out, arising from damage may be photographed with a multi-resolution camera package carrying color infrared film. The locations for photography will vary with seasonal conditions and the time of year of the mission. In order to test these options in the presence of mixed species (of different, overlapping leaf-out), a sequence of images at about one-month intervals will be required, beginning in late-March and followed by later missions in April, May, and even possibly June.
- 3) This procedure is, of course, applicable to other forms of mortality than Winter-kill alone, or avalanching. It should, therefore, be integrated with programs searching for disease locations or insect spread, and programs for mapping forest fire limits.

To summarize, the essential steps in this procedure are:

- Narrowing down the area of search by a careful record-keeping
- Use of multi-time sampling
- Use of multi-stage sampling.

In order to obtain photography over selected areas, both programmed and unprogrammed photography will be required. In addition to the programmed photography, the astronauts should also use the search and track mode with the telescope.

#### 1.5 Relevancy of Experiment

Addresses a difficult area of general forest management and development.

#### 1.6 Role of Man

Search and track for off-axis locations using zoom telescope.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

Astronauts will use search and track mode with the telescope.

#### 1.8 Supporting Research and Technology Required

Nil.

#### 1.9 Targets

Various in Eastern United States. The principal targets will be in commercial forests and in National and State Forests and Parks in those states with significant hill and mountain forests in eastern U.S.A. Almost all the states have sizable acreages. The principal areas for this experiment are Maine (17 million acres forests), New York (12m), Pennsylvania (17m), Virginia (16m), West Virginia (11m), North Carolina (20m), Kentucky (12m), Tennessee (14m), South Carolina (12m), and Georgia (26m).

#### 1.10 Truth Sites

Various, depends on location of severe weather damage of various types.

### 1.11 Orbital Parameters

Various; orbital inclination 50 degrees or higher, 100 - 200 n. mi. altitude; sun angle above 30 degrees.

### 1.12 Data Required by Investigator

Previous satellite and spacecraft photography if feasible to compare changes.

### 1.13 Principal Users

- U. S. Forest Service
- Private forest associations
- Individual lumber companies
- State forest services
- National park service.

### 1.14 Documentation/References

1. Anonymous. Applications of Remote Sensors in Forestry, International Union of Forest Research Organizations. Druckhaus-Rombach & Co., Freiburg, 1971.



## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Late March to mid-June at about monthly intervals.

### 2.2 Frequency of Measurement/Observation

Monthly: March - June.

### 2.3 Total Time Span of Measurement/Observation

Each site, each mission

30 seconds over site  
5 minutes preparation  
5 minutes post-imaging

### 2.4 Solar Elevation Angle

Greater than 30 degrees.

### 2.5 Cloudiness

Five percent scattered; 60 percent solid.

### 2.6 Ground Coverage

Same as camera field for broad area camera.

### 2.7 Resolution

5 meters high resolution camera, 20 meters broad area coverage camera.

### 2.8 Accuracy/Precision

300 meters pointing accuracy.

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Panoramic Camera  
12 cm. (5 in.) film

- b) Correlative Support
  - Pointable Identification Camera
- c) Support Equipment
  - Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Displays
  - Tape Recorders.

## SUMMARY EVALUATION

### AFR5. NATIONAL GRAIN STRATEGY PLANNING

In nations where grain production is a significant cash crop for both internal and external markets accurate assessments of yield and harvest dates are an essential part of economic planning. Conventional data collection techniques are often time consuming, not optimized and inaccurate. The ERTS data can contribute to improvements in planning through multistage sampling but the potential for improved resolution, all weather, and quick response offered by Shuttle (MEO) suggests an increase in data accuracy and timeliness.

The potential to do part of the job with ERTS, EOS and Skylab reduces the significance of this candidate experiment, but does not eliminate the need for its performance on Shuttle. The rating for this experiment is Acceptable - Level 2.

## AFR5. NATIONAL GRAIN STRATEGY PLANNING

### OBJECTIVE

To improve the accuracy of yield prediction and forecasting of harvest dates for the grain crops of nations which suffer from incomplete or inaccurate information for use in planning grain marketing programs. In a global sense, improved information would permit better planning of exports and imports between Northern and Southern Hemisphere countries whose grain crops are harvested during different seasons. Better grain supply information would permit the worldwide supply of grain to be marketed more efficiently throughout the calendar year.

### BACKGROUND AND RELEVANCY

In nations where grain production is a factor in both the internal marketing structure as well as the import/export scene, accurate predictions of expected yield and harvest dates are essential for making sound decisions regarding many aspects of agricultural marketing, such as pricing policy, need for supplemental grain purchases, maintenance of a favorable balance of trade in the agricultural sector, etc. Current techniques for collecting these data are often time consuming and inaccurate, and produce results in a format not amenable to optimum use (i. e., for the wrong land areas, biased by collection techniques, etc.). In addition, results are often not available in time for optimum utility. Although improvements in estimates will no doubt be made by utilizing ERTS-type data in a multistage sampling framework, the potential for further improvements in timing and accuracy exists with the use of space shuttle. Rapid response time and higher image resolution are the advantages to be gained from the Shuttle approach.

### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

The stepwise approach is:

- 1) Delimit range of grain-growing areas using low resolution (100 ft) ERTS-type imagery with supplementary information.
- 2) Stratify these grain areas, using any existing information regarding occurrence of each grain crop, its distribution, and approximate expected yields.

- 3) Use Shuttle to collect higher resolution imagery of selected sample areas. Collect ground data (crop type, vigor and estimated yield, etc.) in a portion of these imaged areas.
- 4) Interpret imagery to estimate acreage of each grain crop, estimate losses expected (due to natural cultural factors), and predict yield.
- 5) Use ground data to adjust interpretation estimates.
- 6) Sequential study of crop development, together with records of post grain development patterns in response to weather, is undertaken to estimate harvest dates and duration of harvest.

Man's role would involve in-flight decisions regarding choice of sample areas (adjustments for cloud cover, poor visibility, etc.).

## SUMMARY EVALUATION

### AFR6. TROPICAL STORM DAMAGE ASSESSMENT AND LOSS PREDICTIONS

Tropical storms can inflict widespread damage to coastal agricultural systems (including forests). Rapid assessment of damage to the agriculture as well as to houses and other man-made structures is valuable for remedial action planning.

Shuttle could possibly provide effective coverage with space-borne SAR. There are significant questions regarding timing, the alternate use of aircraft, etc.

This experiment will undoubtedly be conducted even if on an ad hoc basis; however, sufficient questions remain as to its efficient completion to warrant a careful look prior to final approval. The rating is Acceptable - Level 3.

AFR6. TROPICAL STORM DAMAGE ASSESSMENT  
AND LOSS PREDICTION

Tropical storms can often inflict widespread damage to large coastal areas. Rapid assessment of the damage can lead to minimizing of the effects on loss of life as well as valuable natural resources. In less developed countries with isolated coastlines where tropical storms are common, the role of monitoring from Shuttle might prove invaluable.

The objectives of the proposed experiment are to:

- Delimit area incurring damage from violent storms (hurricanes, cyclones, etc.)
- Estimate resultant crop losses
- Estimate timber losses and establish priorities for salvage operations.

## SUMMARY EVALUATION

### AFR7. INTERNATIONAL WATERFOWL FLYWAY MONITORING

Effective waterfowl management must be built on an international cooperative basis. The need to monitor movements of waterfowl along the entire length of flyways is particularly acute. Space Shuttle may provide an opportunity to follow the movements of large flocks of waterfowl utilizing the potential for high resolution remote sensing. The constraints of timing and resolution place a significant question mark over this proposed experiment. If these constraints can be overcome, this is a valuable contribution to our requirement to view all aspects of the ecosystem of "Spaceship Earth".

Because of the severe constraints listed above, this experiment is rated as Shuttle MEO Acceptable - Level 3. Tests should be conducted in known waterfowl habitat areas on Skylab to ascertain whether the resolution available with the terrain mapping system (10 meters) could contribute useful information when large flocks are present.



## AFR7. INTERNATIONAL WATERFOWL FLYWAY MONITORING

Effective programs for monitoring waterfowl migrations, studying the quality and adequacy of habitat, and working towards effective waterfowl management must be international in scope because of the nature of waterfowl life patterns. The need for monitoring movements of waterfowl along the length of the flyways is particularly acute. Space Shuttle provides the opportunity to follow movements of large flocks of waterfowl by virtue of its high spatial and temporal resolution.

At present, the most intensive efforts towards understanding waterfowl ecology, regulating hunting, and protecting waterfowl habitat are taking place in developed countries. If adequate data on waterfowl population and its concentration and sites where waterfowl prefer to congregate during migration can also be collected in other areas not currently being studied, more ecologically sound waterfowl management programs can be implemented and international cooperation stimulated in this regard.

The objectives of the proposed experiment are to:

- Follow migration patterns of waterfowl, determining:
  - when they congregate
  - how they travel from Summer to Winter grounds
  - where they do and do not congregate along the way.
- Develop better understanding of life cycle and movements of waterfowl populations; for example, explore pathways, movements, and habitat in South America where information is scarce and management programs are rudimentary.
- Foster international cooperation by sharing information during migrations that will help nations to better manage waterfowl resources.
- Evaluate intensity of habitat use and inventory the amount of usable habitat--provide reports on critical areas where habitat is in danger from development or otherwise limited.

## SUMMARY EVALUATION

### AFR8. FOREST DISTURBANCE MONITORING AS A MULTISTAGE PROBLEM

In order that commercial forest land is maintained in a state of high productivity, disturbed areas resulting from logging, clearing fire and wind throw must be stabilized and replanted without delay. Since forest disturbances may occur in remote areas they are exceedingly difficult to diagnose adequately with existing techniques. Aircraft may be applied but only if they know where to look. Data from Shuttle regarding the occurrence and extent of forest disturbances on a regional basis would be valuable for planning remedial action and vectoring aircraft and for ground teams into affected areas.

This candidate experiment can best be conducted as an add-on to a priority mission. Future unmanned space systems may well meet the need.

The Shuttle (MEO) rating of this experiment is, therefore, Not Selected.



## SUMMARY EVALUATION

### G1. RAPID GEOLOGIC RECONNAISSANCE MAPPING

Large areas of the earth have not yet received even the simplest form of geologic mapping. The advent of synthetic aperture side-looking radar (SAR) on Shuttle will permit regular semi-automated collection of SAR geologic reconnaissance data which can be usefully analyzed to provide geologic structural analyses and thereby permit estimation of large areas of mineralization potential.

This experiment will be a necessary ancillary to a Shuttle-borne SAR-system development and testing program. Man will have a significant role in system calibration, initial data review, and various on-board analysis activities. This is an important experiment and is rated for Shuttle MEO as Acceptable - Level 1.

## G1. RAPID GEOLOGIC RECONNAISSANCE MAPPING

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Area

Geology resource management.

#### 1.2 Experiment Objective

Develop a system of acquiring reliable reconnaissance geologic maps of large portions of the earth's surface using semi-automated methods in order to assess mineral resource potential and inventory known resources.

#### 1.3 Experiment Background

Rises in exploration costs and resource demands will require developing rapid, relatively inexpensive, methods of assessing the mineral and fossil fuel potential of large remote areas. This system or methodology would be an integral part of any worldwide resource management system.

Several workers have devoted considerable effort to investigating the spectral response of various rock types. Lyon (1972) and others have reported encouraging advances in these efforts using an infrared spectrometer mounted in a low flying aircraft. Whether such discrimination of rock types can be made from a spacecraft is yet to be determined.

The concept of matching the identified spectra against the responses in several bands (four or more) of the multispectral scanner (MSS) also has not been investigated but seems feasible using onboard computer processing.

#### 1.4 Proposed Technical Approach

Timing of the launch would not be linked to any particular event, but should be timed for optimum climatic conditions in the target areas. The method will be to collect as many types of data as possible that are likely to aid in identifying rock types, delineating lithologic differences, and fractures over desert areas of the world. Deserts are chosen in order that vegetation and soil moisture introduce a minimum number of ambiguities into the spectrometric and radiometric measurements.

The initial data collection pass should be over a desert area for which good regional maps exist in order to check results obtained from the spacecraft instrumentation against known conditions and further

calibrate the instruments. If results are favorable, data should be collected over other areas and subjected to the same processing.

Both high resolution and broad area coverage with color and color infrared photography collected during the desert passes will serve as permanent records of the ground track and as a plotting base for processed geologic information after the flight. A high resolution infrared spectrometer and a high resolution, calibrated, multispectral infrared scanner will examine the nadir of the Shuttle as it traverses desert areas. These data will be recorded on magnetic tape and simultaneously fed to an onboard computer. The computer will match spectra acquired against a library of spectra known to be associated with specific rock types in order to identify the rock types overflown. The spectrometric data will identify lithologic boundaries along the nadir of the spacecraft. In order to extrapolate the boundaries laterally, the computer will match spectra against the intensity levels present in the multiband infrared scanner imagery. Further, the computer will examine scanner imagery for linear elements. Boundaries and linear elements will be displayed on a CRT display which also contains a registered image of the known geology (or topography where the geology is not known).

It might be possible to extrapolate boundaries and linear features over an even wider area by using multiband SAR imagery (which is extremely sensitive to changes in surface morphology and roughness) and correlating this against the thermal scanner imagery (provided the SAR data can be recorded on tape as well as film and problems of image congruency between the SAR and scanner data can be resolved).

At least two passes over each area will be required: one in daytime (solar elevation 25 - 40 degrees) for photography and one at night for the infrared radiometers, and spectrometers. Radar could be used during both passes.

The strategy will be to cover a well known area to check the feasibility of the approach and eliminate redundant or unnecessary sensors or bands. If the preliminary results are satisfactory, the experiment should be repeated over little known desert areas. The results of these passes will be checked against any available information. Based on existing maps of the preliminary test site, additional spectra of lithotypes

could be entered into the computer library of spectra, thus increasing the computer's potential for automated discrimination.

The experiment will also be attempted in more vegetated areas. In these regions only spot data will be available where outcrops are not covered with vegetation. Even with these constraints, the thermal IR scanner should provide valuable data that can be interpreted in conjunction with the photography and radar.

The onboard geologist will need comprehensive knowledge of the regional geology in areas overflown as well as a background in thermal infrared remote sensing techniques and data. He would monitor the data acquired and the interpretations made by the computer and portrayed on the CRT. Based on the initial results he may choose to change the scope of the experiment by extending the test to other than desert areas (other possibilities would be semi-arid areas, extensively glaciated areas or high latitude tundras). Some experimentation will also be necessary to ascertain whether it is worthwhile to sacrifice the color and color infrared photography possible during the daytime for the better thermal infrared results possible at night. The geologist would also be able to aim instruments at targets of opportunity.

#### 1.5 Relevancy of Experiment

Worldwide information on mineral and hydrocarbon resource potential.

#### 1.6 Role of Man

The instrumentation would have to be calibrated for operation at spacecraft altitudes.

Man would have to decide whether preliminary results justified further runs and which data or image elements are redundant and which are critical. He could make onboard adjustments to enhance the quality of the results.

Man could take advantage of targets of opportunity, e. g., unique lighting, atmospheric or snow fall/melt conditions.

### 1.7 Impact of Experiment on Shuttle Sortie Mission

Will require extensive onboard processing. (This requirement could be significantly reduced if found to be untenable.) The multiband radar implies large power requirements.

### 1.8 Supporting Research and Technology Required

- 1) Development of a spaceborne multifrequency radar system
- 2) Further research into the spectra of lithotypes under various conditions
- 3) Development of the necessary computer programs to integrate the spectrometric/radiometric data with the scanner data
- 4) Development of a multiband imaging scanner and spectrometer with high resolution (spatial and spectral, respectively) in the 3 - 14 km region.

### 1.9 Targets

Remote relatively unexplored areas of the world, particularly deserts.

### 1.10 Truth Sites

Preliminary: Deserts of the western U.S. (Great Basin and Southwest Texas), central desert of Australia, Gobi Desert.

Unknown: Kalahari Desert, desert areas of Sonora and Chihuahua, Mexico, etc.

### 1.11 Orbital Parameters

Inclination 40 degrees or more; preferred altitude, 100 - 200 n. mi., near circular.

### 1.12 Data Required by Investigator

#### From Shuttle:

- Photography
- Multispectral scanner data
- Radiometer data
- Spectrometer data
- Radar imagery
- Ephemeris data

#### Other Sources:

- Geological maps and reports existing on areas of investigation
- Library of lithologic spectra
- Ground verification of particular features



### 1.13 Principal Users

- Development planners
- Exploration geologists
- Mineral resource managers.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

This experiment can be conducted at any time of year in periods of minimum cloud cover.

### 2.2 Frequency of Measurement/Observation

One or two times complete coverage of desert areas. Repetition cycle is not critical.

### 2.3 Total Time Span of Measurement/Observation

To be determined.

### 2.4 Solar Elevation Angle

N/A for nighttime passes; 25 - 40 degrees for daytime passes.

### 2.5 Cloudiness

Cloud free (<5 percent). This should present no problem in desert areas.

### 2.6 Ground Coverage

120+ km for imaging sensors. Total coverage would amount to on the order of 1 million km<sup>2</sup> on the first sortie. If the method is successful, coverage would be extended on subsequent missions.

### 2.7 Resolution

Photography: High resolution, 5 m or less; low resolution 20 m or less.

Thermal Infrared Imagery: 50 m

Radar: Approximately 20 m.

### 2.8 Accuracy/Precision

Location accuracy to ±1 km.

## 2.9 Shuttle Instrumentation/Equipment Requirements

### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
- Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
- High Resolution Wideband Multispectral Scanner  
(20 Spectral Bands)
- LWIR Spectrometer
- Multifrequency Wideband Synthetic Aperture Radar  
(Medium Coverage, Low Resolution Mode)

### b) Correlative Support

- Pointable Identification Camera

### c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Display
- Tape Recorders.

## SUMMARY EVALUATION

### G2. COASTAL GEOLOGY AND GEOMORPHIC PROCESSES

Coastal geologic and geomorphic provinces are, in many parts of the world, e.g., Malaysia, well endowed with various mineral deposits, notably placer type. Careful review of the coasts with multispectral sensors could yield significant new areas for exploration. The wide area view provided by a satellite is essential to permit analysis of the interrelations among the coastal geomorphic provinces and, for example, major drainage patterns.

This is a valuable experiment pertinent to future mineral and hydrocarbon exploration over more of the world's coasts.

The overall experiment is rated for Shuttle (MEO) as Acceptable - Level 1. This rating is based on the assumption that a regional evaluation, extending more than 50 miles inland from the coast, will be necessary for effective evaluation of the mineral potential. This experiment will also be a significant test and development item for the Shuttle-borne SAR.

## G2. COASTAL GEOLOGY AND GEOMORPHIC PROCESSES

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas

Geology, geomorphology, coastal management and engineering, engineering geology.

#### 1.2 Experiment Objectives

To examine in detail the coastal processes occurring in several regions under various sets of weather conditions and to examine and interpret near-shore geologic features with the aim of extrapolating these under water.

#### 1.3 Experiment Background

Coastal geomorphic and geologic processes are of great scientific, environmental and economic interest. Study of present day coastal processes provides the keys to interpreting conditions of deposition of many sedimentary rock units. This information, in turn, is valuable for interpreting geologic history and for mineral (diamonds, magnetite, monazite, etc.) and hydrocarbons exploration.

The dispersion patterns of sediment indicate current and wind directions and the deposition sites of sediment, some of which may contain economically valuable minerals. Knowledge of marine sediment transport patterns is also extremely valuable in conducting beach stabilization and dredging programs.

Study of nearshore geological features can aid the interpretation and understanding of geologic features in deeper water that are known only from geophysical information and bottom topography. This information will contribute to understanding coastal tectonics and aid in exploration for nearshore mineral and hydrocarbon deposits.

A large quantity of information on coastal areas will be developed by ERTS and Skylab programs and associated aircraft collection efforts. Shuttle missions will be coordinated to take maximum advantage of this existing information.

#### 1.4 Proposed Technical Approach

Shuttle missions and coverage will be designed to supplement, refine and integrate exiting information on coastal processes. Emphasis will be on collecting detailed or high resolution data to resolve ambiguities in previous studies.

The instrument complement of Shuttle will examine selected coastal sites repeatedly at various times of the year and under various weather conditions. It would be highly desirable (even though many sensors, especially in the visible region, would be useless) to examine test sites during hurricanes or other severe storms in order to gain information on the dynamics of catastrophic coastal process.

Coverage during "normal" weather conditions as well as severe weather conditions will provide invaluable information on temporal differences in rates of coastal geomorphic processes.

Repeated passes over particular sites during a single sortie will provide time lapse coverage useful for understanding dynamic processes such as tidal flow, currents, and dispersion of sediment plumes. It is desirable to have repeated coverage during unusual events such as abnormal discharge of sediment as the result of inland flooding or particularly high influx of pollutants.

In order to extract the maximum amount of information from data collected, Shuttle passes will be coordinated with an extensive surface information collection program. The surface collection program will be designed to acquire data necessary to calibrate the space acquired data (e.g., sediment load, depth, salinity, surface temperature, wave height and frequency, current velocities, etc.). These data will permit development of interpretive surrogates such as water color in place of sediment load, tone in multiband imagery for water depth, scatterometer signal strength for sea state, etc.

Displays on board will allow the marine geologist/oceanographer to carry out near real time comparisons of the remote sensor data with seismic profiles or aeromagnetic maps. These types of comparisons will be particularly valuable during data collection efforts at night or in bad weather.

Fortunately many coasts, even in the humid tropics, are cloud free even when adjacent land masses are covered. However, for the purpose of this study, it will be desirable to collect data during storms. Thus, in addition to sensors useful under clear conditions (cameras with color and color infrared film, visible and infrared multi-spectral cameras, radiometers and spectrometers, the Shuttle will carry a microwave scatterometer/radiometer for sensing sea state and a multi-frequency, synthetic aperture, side-looking radar. The radiometer/scatterometer would have a very large footprint (poor resolution), and would not be useful for detecting or discriminating shoaling or wave defraction around islands. Preliminary considerations suggest that a high resolution synthetic aperture multi-frequency, multi-polarization side-looking radar flown at space altitudes and speeds would be capable of imaging wave and swell development, shoaling, and wave defraction patterns. These phenomena have been imaged using a brute force side-looking radar but have not been seen in synthetic imagery. This type of imagery and a 90 minute repeat cycle would be extremely valuable for studying the dynamics of coastal processes during storms (only extremely heavy rainfall would degrade the imagery).

This radar will have to be developed and tested in aircraft prior to mounting it on Shuttle. However, once it is perfected, its multifrequency multipolarization cloud penetrating capability will make it an extremely useful tool in a large number of fields such as geology, land-use assessments, agriculture, forestry, etc.

This experiment will be an excellent opportunity to test and evaluate the radar's performance from space.

### 1.5 Relevancy of Experiment

The data collected during this experiment could be of value to an international pollution inventory or monitoring program as well as contribute to the ends of this experiment such as:

- Study and assess coastal erosion
- Study sediment transport in the coastal and nearshore areas
- Investigate deposition in the coastal zone

- Study and monitor the dynamics of geomorphic processes during storms or exceptional influx of sediment
- Extrapolate onshore and shallow water geology into deeper waters
- Monitor and study the movements of pollutants in the coastal environment.

#### 1.6 Role of Man

- 1) Equipment tending (particularly important for instruments such as SLAR)
- 2) Exercising real time judgement as to which data are essential and which superfluous in order to eliminate collecting non-essential data as a means of data compression. Warn of impending disaster based on observations during storms.
- 4) Take advantage of targets of opportunity.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

Except for the need to study conditions under particular sets of weather conditions and to examine particular coastal areas, this experiment will not control either launch or orbit and will be a secondary experiment.

#### 1.8 Supporting Research and Technology Required

The largest task will be development of the synthetic aperture radar.

#### 1.9 Targets

The coast of England, Northern California coast, Gulf Coast of the U.S., the Greek Isles of the Aegean, East Coast of Sumatra, mouth of the Amazon, United States East Coast corridor eventually. The experiment should eventually be directed toward coverage of all the world's coastal areas.

#### 1.10 Truth Sites

Will be established in each of the above areas. These sites will provide the data necessary to calibrate the imagery.

#### 1.11 Orbital Parameters

Altitude: 100 - 200 n. mi.

Inclination: 60 degrees desirable, 40 degrees acceptable.



### 1.12 Data Required by Investigator

From Space:

- Multiband, and high resolution photography (color and color IR)
- Multispectral scanner imagery (visible and IR)
- Side-looking radar imagery
- Radiometer/scatterometer data

From the Surface:

- Existing studies in geology, oceanography, etc.
- Geophysical surveys of off-shore areas
- Water temperature
- Sediment load
- Wind velocity
- Wave data
- Sea color at the surface
- Current patterns
- River discharge rates.

### 1.13 Principal Users

The results of these studies will be exceedingly valuable to:

- Coastal engineering programs (dredging, erosion prevention, road building, building construction, etc.)
- The understanding of the effects of storms on coasts, consequently contributing to diminishing losses resulting from those storms
- The overall understanding of coastal geomorphic and sedimentation processes
- Exploration for placer mineral deposits and hydrocarbon accumulation in the coastal zone.

Consequently, the results will be of use to:

- Coastal, marine, mineral and hydrocarbon exploration geologists
- Geomorphologists interested in the coastal zone
- Planning agencies in the coastal zone
- Coastal engineers.

1.14 Documentation/References

R. L. Folk  
F. Sheppard  
Pettijohn  
Sloss and Krumbein

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Depends on the target area.

### 2.2 Frequency of Measurement/Observation

Several areas should be covered during storms as well as during fair weather. During storms, 90 minute repeat coverage would be desirable.

### 2.3 Total Time Span of Measurement/Observation

Each site would be observed for a total of several minutes.

### 2.4 Solar Elevation Angle

60 degrees desirable; 40 degrees acceptable.

### 2.5 Cloudiness

As small a percent of cloud cover as possible for clear weather observations. Storm observations will be conducted with complete cloud coverage.

### 2.6 Ground Coverage

10,000 + n. mi. of flight line coverage required.

### 2.7 Resolution

Photography will be used to provide high resolution (~8 m) coverage. Scanners and radar will be of the order of 15 - 50 m; resolution requirements of the radiometer/scatterometer will be approximately 1.5 Km.

### 2.8 Accuracy/Precision

Will not be a particular issue except to the extent of having plotting done accurately enough to update existing coastal maps and charts.

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film

- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
  - Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
  - High Resolution Wideband Multispectral Scanner  
(20 Spectral Bands)
  - LWIR Spectrometer
  - Multifrequency Wideband Synthetic Aperture Radar  
(Medium Coverage, Low Resolution Mode)
- b) Correlative Support
- Passive Multichannel Microwave Radiometer (PMMR)
  - Pointable Identification Camera
  - Data Collection System
- c) Support Equipment
- Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Display
  - Tape Recorders.

## SUMMARY EVALUATION

### G3. REDUCED GRAVITY EXPERIMENTS/ DEMONSTRATIONS IN GEOLOGY

This candidate experiment is another in a class of zero-G laboratory programs. The graphic demonstrations possible would prove invaluable for teaching, creating new type physical models, etc.

In zero-G experiments the 5 - 7 day Shuttle sortie mission is unique because of the short experiment duration required and because man is both important and necessary to their successful accomplishment. The overall Shuttle (MEO) rating is Acceptable - Level 1.

### G3. REDUCED GRAVITY EXPERIMENTS/ DEMONSTRATIONS IN GEOLOGY

#### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

##### 1.1 Associated Problem Areas

Structural geology, tectonics, geologic modeling.

##### 1.2 Experiment Objectives

Graphic demonstration of fundamental geologic principals, particularly in the areas of stress-strain relationships, fluid dynamics of the earth's interior, and modeling theory. The experiments would take advantage of the reduced gravity on Shuttle and will be recorded on film.

##### 1.3 Experiment Background

In geologic modeling experiments on the earth, gravity (g) cannot be ignored. The Shuttle offers an environment in which g will be completely absent or present to varying but controllable and predictable degrees. Such an environment is ideal for testing or demonstrating principles whose veracity is somewhat masked or clouded by the gravity of the earth.

Several fundamental principles can be tested or demonstrated in reasonably simple experiments and hence are candidates for this Shuttle experiment.

Statements to the affect that a particular lithologic body is weak and consequently cannot transmit stress over large distances are frequently made in geologic literature. This is patently untrue and can be easily demonstrated in a zero-g environment with a thin slab of gelatin, a movie camera and a bit of dexterity.

Although the general concept and outline of plate tectonics are generally accepted, considerable discussion continues about the geometry of convection cells in the mantle (if they are present at all). Earthbound experiments in this area are somewhat limited because of unidirectional g, which can be avoided onboard Shuttle.

Fundamental to all geologic modeling is the concept that if physical dimensions (length, width, height) are reduced, then other parameters such as viscosity, Poisson's ratio, Young's modulus and time (or rate)

must also be adjusted in order to maintain a constant modeling ratio. Gravity is considered but assumed constant because of experimental limitations at the surface of the earth. It would be informative to test the effect of variable  $g$  on the conduct of several simple experiments.

#### 1.4 Proposed Technical Approach

The overall concept is that there are a number of phenomena and processes for which it would be informative to observe the effect of removing or radically altering the acceleration due to gravity. The filmed results of experiments on demonstrations performed in near-zero- $g$  conditions would be extremely valuable for teaching purposes. Three such experiments described briefly below are of interest in geology. Many other such demonstrations would be valuable to other fields.

##### Stress Transmission

If a stress is applied to one surface of an unconfined body under zero gravity and zero friction conditions, the body will accelerate unless the viscosity of the body is exceedingly low compared to the rate at which the stress is applied. That is, if the stress is applied slowly enough, any body will accelerate rather than deform. This demonstrates that even very "weak" materials (i. e., low strength or viscosity) are capable of transmitting stresses over their entire extent.

The method of demonstrating this concept (which most geologists have been taught, but do not emotionally accept) will be to have a number of slabs or sheets of substances with different but low viscosities (such as petroleum jelly, gelatin, soft clay, etc.) and apply a stress uniformly across one end of each slab. Stress will be applied slowly at first. Under these conditions all slabs will accelerate. As the rate of stress application increases, the lower viscosity materials will deform as well as accelerate.

##### Mantle Convection

The feasibility of convection cells in the mantle is a major topic of discussion. If their existence is assumed, their stability geometry and dynamics distribution, etc., remain topics of controversy. The distribution, geometry, and behavior of these postulated thermal convection cells can be studied by using a transparent outer sphere, inner heated

spheres of various sizes, and fluid between that would represent or model hot viscous mantle material. The different size smaller spheres will allow testing of various hypotheses about the thickness of the viscous shell or asthenosphere. The viscosity of the filling material should be adjustable (by adding or extracting solvent) in order to test various assumptions about viscosity to thickness relationships. The thermal response (conductivity, drop in viscosity with rise in temperature, etc.) should parallel what is known about mantle material. Various reasonable or postulated shell thickness, viscosity and core temperature arrangement should be tested and photographed (the filling material would have to be transparent and have some sort of marker or characteristic--suspended particles or minor change in color with change in temperature) that will allow observation of any convection cells that form.

#### Effect of g on Deformation

A simple series of model deformation experiments will be repeated several times during a sortie mission holding everything constant except g. All values of g will be kept low. The results of the experiments will be studied to see if the changes in rate resulting from the change in g substantiate the concept of a model or process constant.

The films resulting from each of these experiments will be exceedingly valuable for research and teaching.

#### 1.5 Relevancy of Experiment

The goal of these experiments would be to produce a series of movies that could be used in teaching and demonstrating particular principles.

#### 1.6 Role of Man

Man would need to set up and run the experiments and record them on film or video tape. It might be possible to automate these demonstrations but the cost would be astronomical. Geologic modeling experiments are notorious for requiring minor adjustment in the model set up before successful runs can be made.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

This would be an add-on experiment and require only space and a geologist and otherwise not affect the Shuttle mission. It could be



conducted by a geologist onboard for other experiments during times that the other experiments did not require his full attention.

#### 1.8 Supporting Research and Technology Required

Gravity meter to accurately measure very low values of  $g$  and the orientation of the field. Fluids with the proper viscosity and photographic properties for the convection experiment (these fluids probably exist and it is only a matter of locating and testing rather than development). Further research into the thermal and mechanical properties of mantle materials.

#### 1.9 Targets

The experiment would be conducted completely within Shuttle.

#### 1.10 Truth Sites

None.

#### 1.11 Orbital Parameters

The only requirement on orbits is that during the testing of modeling theory, gravity on board Shuttle would need to be increased above the 0 level.

#### 1.12 Data Required by Investigator

Environmental parameters inside Shuttle, physical parameters of the substance being investigated, time or rate of experimental progress, and the photographic record (movie) of the experiment.

#### 1.13 Principal Users

Teachers and researchers in modeling theory.

#### 1.14 Documentation/References

V. V. Beloussou  
M. K. Hubbard  
R. Kehle

2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

2.1 Time of Year/Season

Not important.

2.2 Frequency of Measurement/Observation

Experiment recorded by three movie cameras at about 16 frames/second.

2.3 Total Time Span of Measurement/Observation

Estimate to be about three hours.

2.4 Solar Elevation Angle

Not applicable.

2.5 Cloudiness

Not applicable.

2.6 Ground Coverage

Not applicable.

2.7 Resolution

Not applicable.

2.8 Accuracy/Precision

$\pm 1/2$  mm of actual movement (translation or deformation)

2.9 Shuttle Instrumentation/Equipment Requirements

Simplified geologic modeling set up (strain table and motors) and the necessary measuring equipment (strain gages, thermocouples, gravity meters, etc.), movie or video cameras for recording experimental progress and results.

## SUMMARY EVALUATION

### G4. GEOLOGIC AND TOPOGRAPHIC MAPPING OF MOUNTAINOUS AREAS OF THE WORLD

It has long been recognized that the mountain ranges of the world (in a geologic sense) are some of the most interesting areas of the world. With the acceptance of the plate tectonics and sea floor spreading hypotheses many mountainous areas have been identified as probable paleo plate boundaries or sutures. Thus, understanding of these areas is fundamental to testing and understanding of the plate tectonics theory. Aircraft mapping of many of these high mountain areas is either impossible or unacceptable because of the large object angles involved. The Shuttle system with its capability for SAR offers the first chance for high resolution, low distortion, maps of the high mountain areas.

This experiment is extremely valuable and is rated for Shuttle (MEO) as Acceptable - Level 1.

#### G4. GEOLOGIC AND TOPOGRAPHIC MAPPING OF MOUNTAINOUS AREAS OF THE WORLD

##### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

##### 1.1 Associated Problem Areas

Geology, cartography and general resource management.

##### 1.2 Experiment Objectives

To develop the methodology and eventually carry out a worldwide program of resource inventory in the mountainous regions of the world.

##### 1.3 Experiment Background

It has long been recognized that the mountain ranges of the world (in the geologic sense) are some of the most interesting areas in terms of answers to fundamental geologic problems and in terms of potential for mineral and energy resources. With the general acceptance of plate tectonics and sea floor spreading hypotheses, many of these areas have been identified as probable paleo plate boundaries or sutures. Thus, understanding these areas becomes fundamental in the testing and understanding of hypotheses associated with plate tectonics theory. At the same time these areas, often areas of considerable local relief, present a host of practical problems for geologic and topographic mapping and general resource inventory. Many of these areas lie substantial distances from population centers and survey bases. Many are located in areas of harsh climate, deserts and high latitudes. The high relief usually associated with these areas presents a barrier to transportation (and hence investigation) and in many instances produces local climatic conditions (cold, clouds, high rainfall, etc.) that make surveying using conventional ground and airborne techniques difficult. The extremes of relief make the conversion of photography from conventional altitudes to topographic maps by photogrammetric means extremely difficult.

##### 1.4 Proposed Technical Approach

Because precise timing is not necessary and, in fact, optimum timing would vary from place to place, this experiment would be carried out in conjunction with other experiments. That is, data would be collected

during those portions of orbits during a particular mission that were over or approximately parallel to mountain ranges. Collection of all the data necessary for the experiment would extend over several missions and many months. The requirement for data over mountain ranges of the world would be entered as a standing requirement on any sortie mission.

Data will be acquired by a variety of Shuttle-borne sensors. However, high resolution multifrequency side-looking radar will be the primary sensor because of cloud problems. High resolution multiband scanner imagery and multi-spectral photography would be other important types of data to collect, as possible. Supplementary data would be passive microwave imagery, multiband thermal IR scanner imagery, laser altimetry of specific points and the sub-satellite track and very high resolution photography of specific points.

Selection of points for specific attention during overpasses would be based on imagery acquired during previous passes, onboard displays of existing maps, interpretations and imagery, and pre-planned lists of high interest point targets.

Multiple passes over the same areas during the same or different Shuttle missions would offer the opportunity of acquiring photographic and other imagery during times of optimum sun angle, atmospheric conditions or snow condition. Features not usually recognizable are often seen in these types of imagery. Thus, whenever Shuttle is scheduled to overfly a mountainous area, the onboard scientists should be prepared to collect imagery and data. This caveat also applies to radar imagery because repeated looks from different angles and stereo radar imagery greatly increase the quality and quantity of information extractable from the imagery.

The data acquired would be used to correct existing maps and extend or construct maps in areas not previously topographically mapped. These maps would then act as a base for compiling resource information.

The data acquired would be subjected to a variety of types of interpretation (automatic, man/machine, and manual) all directed at extracting information on geology and assess the potential for mineral deposits.

Areas identified as having a high potential for mineral deposits would become point targets of high interest on subsequent Shuttle sorties.

The data on resources would be entered into a worldwide resource inventory data bank. Fundamental geologic data (major structural elements and lithologic units) would contribute a comprehensive understanding of global tectonics.

The potential for serendipity in this experiment is high relative to many other types of geologic experiments. Possible examples include landslides, volcanic eruptions, floods, etc. It is assumed that appropriate equipment (binoculars, cameras, etc.) and communications links (e.g., direct links to volcanic observatories) necessary to capitalize on these types of good fortune would be included in the Shuttle payload and support arrangements.

#### 1.5 Relevancy of Experiment

Information on potential for fossil field and mineral deposits in mountains.

Fundamental geologic information pertinent to understanding regional and worldwide tectonics and geology.

Basic topographic, geographic, and geodetic data on poorly mapped, little known, inaccessible regions of the world.

Data could also be used for forestry and water resource applications.

#### 1.6 Role of Man

Man's primary roles would be in the care-taking of non-space hardened equipment, operating sensors at appropriate times, selecting targets of special interest (opportunity) and direct special (particularly high resolution) sensors at these targets. His presence also would reduce collection of useless data (e.g., visible region and IR imagery of cloud covered regions) and provide a potential for real time interactive exchange between the sensor platform and ground researchers.

### 1.7 Impact of Experiment on Shuttle Sortie Mission

Acquisition of data over some particular mountainous terrain could be a major objective of a given sortie mission. However, it is assumed that the data necessary for this experiment would be acquired as a secondary or tertiary objective during a number of sortie missions.

### 1.8 Supporting Research and Technology Required

- Further refinement of multi-frequency sidelooking spaceborne radar.
- Further research in interactive computer displays.
- Further research in the automatic interpretation of multiband photography, multispectral scanner imagery, and radar.

### 1.9 Targets

Mountainous regions of the world, particularly those that are little known and poorly mapped (i.e., those in the humid tropics and high latitudes, e.g., New Guinea, Southern Andes, various Antarctic ranges, mountains of Greenland, Himalaya/Hindu Kush ranges, Tibet Plateau, etc.).

### 1.10 Truth Sites

The system of data acquisition processing interpretation and analysis should be tested on a relatively well known area such as the Rocky Mountains, the Alps, or the Sierra Nevadas.

### 1.11 Orbital Parameters

Virtually any orbit between 100 and 400 nautical miles altitude (the lower, the better) that passed over a mountainous area would be potentially useful. In general, the more nearly such an orbit paralleled a mountain range, the better it would be (though for some radar imagery it would be desirable to have an orbit that intersected a given mountain range at a large angle).

### 1.12 Data Required by Investigator

Shuttle acquired imagery and data: radar, photography scanner imagery, radiometry data, altimetry data, ephemeris data.

Existing maps, reports, etc. should be consolidated for viewing onboard the Shuttle, as well as acting as a basis for post-mission interpretation and analysis.

### 1.13 Principal Users

Geological surveys, resource development, management and control organizations of countries in which mountain ranges are located.

Regional and international planning and development organizations (e.g., UN, OAS, European Common Market, etc.).

Geological investigators and theorists.

### 1.14 Documentation/References



## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Dependent upon area; generally times of minimum cloudiness.

### 2.2 Frequency of Measurement/Observation

One time coverage of mountainous regions is a minimum. Any repeated coverage would be useful.

### 2.3 Total Time Span of Measurement/Observation

Estimated six hours total time required.

### 2.4 Solar Elevation Angle

20 - 60 degrees acceptable.

### 2.5 Cloudiness

Radar chosen to circumvent the cloud observation problem. However, visible and infrared data will require that the cloud cover not exceed 20 percent.

### 2.6 Ground Coverage

Estimated to be approximately 120,000 km of ground track coverage required.

### 2.7 Resolution

20 m or less for radar and 5 m or less for photography.

### 2.8 Accuracy/Precision

Geodetic location accuracy to  $\pm 1$  km.

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
- Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only

- High Resolution Wideband Multispectral Scanner (20 Spectral Bands)
  - LWIR Spectrometer
  - Multifrequency Wideband Synthetic Aperture Radar (Medium Coverage, Low Resolution Mode)
- b) Correlative Support
- Laser Altimeter/Scatterometer
  - Passive Multichannel Microwave Radiometer (PMMR)
  - Pointable Identification Camera
- c) Support Equipment
- Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Displays
  - Tape Recorders.

## SUMMARY EVALUATION

### G5. EARTHQUAKE DISASTER PREVENTION (ACTIVE FAULT MONITORING)

Thousands of people have died as the result of earthquakes produced by uncontrolled slippage along faults in various parts of the world. Experiments are planned, in the late 1970s, to attempt to induce controlled slippage along the San Andreas fault in California. If there are significant surface observables associated with this controlled slip, high resolution multispectral observations from Shuttle might provide novel insights into the regional slip mechanisms of the fault and thereby provide a means to monitor fault zones in various parts of the world.

This is an important, but difficult, experiment. The timing of the Shuttle overpass with the ground-based experiment is fairly critical and the estimate of the potential observables is difficult. The overall rating of this experiment for Shuttle (MEO) is Acceptable - Level 2.

## G5. EARTHQUAKE DISASTER PREVENTION (ACTIVE FAULT MONITORING)

### OBJECTIVES

To learn as much as possible about an active well-monitored fault in the hopes that information gained may contribute to prediction of earthquake generation caused by fault movement.

### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

The test fault and the San Andreas fault (if it is not the test fault) would be covered using medium and high resolution color infrared photography (during daytime passes) and carefully examined with calibrated multispectral infrared scanner and microwave scanner on all passes. In order to increase the resolutions of these instruments, the dwell time could be increased by using them in a shift-lock-on-scan mode controlled by the on-board scientist. The scan data should be recorded digitally and photographically. The digital data should be stored on-board so that data from two or more different passes could be compared by the on-board scientist during non-imaging portions of the orbit. These comparisons could conceivably reveal areas of anomalous change that might require further attention or more detailed study. On-board equipment should include the computers and equipment necessary to view two runs over the same area simultaneously, superimpose a positive of one and a negative of the other, perform simple differencing, and to superimpose a view or a differenced image on a geologic map of the area.

During the overflights a variety of ground measurements should be collected. These should include:

- Temperatures at various points at the time of the passes
- Temperatures and flows of springs along the fault trace
- Data from the stain net in order to pinpoint areas where the fault is locked, and areas where the fault is creeping (the thermal regimes adjacent to these two types of fault conditions should be different and perhaps measurable)
- Immediate reconnaissance of anomalies observed in data to aid real time interpretation.

Points on the San Andreas and test fault surveyed seismic strain net should be marked so that they can be identified in imagery. This would provide a highly accurate geometric guide for the imagery and a basis for comparison, if it is possible to observe the fault before and after movement.

Changes observed along the test fault or fault segment during strain release would be compared to changes along the San Andreas. Based on these observed changes, it may be possible to isolate phenomena that indicate incipient or impending fault movement. If the experiment is successful, it may be possible to develop an automated earthquake prediction satellite monitoring system. The potential for reducing life and property loss is tremendous.

There is a small but real possibility that during the flight a seismic event may occur along the fault. This would provide same day comparison of conditions before and after finite movement on the fault. In light of this, it is crucial that the spacecraft be able to communicate with the various seismic observatories.

Because the area adjacent to the San Andreas is extremely active geologically, it may be possible to observe various other types of short duration geologic events such as:

- Landslides
- Large-scale coastal slumping
- Mud flows.

Recently there has been considerable discussion of artificially releasing accumulated stresses or strain energy along major strike-slip faults by selectively injecting and withdrawing fluids in bore holes drilled at intervals along the fault. Shuttle would be the ideal platform from which to monitor this type of operation. The onset of such an operation would be an excellent time to launch a Shuttle mission. This type of operation would require an on-board scientist to point instruments at the prime targets and track them during a pass.

In addition to the geologic information interpretable from the data, there are a number of other purposes that can be served:

- Flow patterns in bay and coastal areas seen in a time lapse fashion
- Spectral response of different vegetation types at different times of day
- Water pollution of bays and rivers
- General geologic mapping and tectonic analysis
- Land use and urban development in the West Coast population corridor
- Geothermal prospecting
- Mineral exploration
- Data base for seismic threat mapping

If scanner design and calibration are sophisticated enough, it may be possible to reconstitute synthetic thermal spectra of particular points on the ground from the imagery data. These may be used in recognizing different rock types.

As in all geologically oriented experiments, the presence of man in orbit offers the possibility of obtaining chance pictures of geologic structures with the optimum lighting conditions and cloud free imagery of areas normally covered by clouds.

Man would need to continuously monitor the passes over targets and spend considerable time comparing imagery from various passes over the strain release fault segment acquired during strain release.

#### BACKGROUND AND RELEVANCY

In the conterminous U.S., people sustaining the largest threat from earthquake disasters are those living along the trace of the San Andreas and related faults in California. In order to examine this set of potentially dangerous geologic structures, Shuttle would be launched into an orbit roughly parallel to a segment of the fault between San Francisco and Los Angeles. It would be desirable for each successive orbit to pass over the fault in order to observe the fault every two hours or so throughout a day or several days. It would be ideal if the experiment could be performed before and after movement of the fault.

Several groups are studying the possibility of artificial strain release along major earthquake generating strike-slip faults. The theory is that the ends of a fault segment with considerable accumulated strain could be "locked" by pumping fluid out of wells penetrating the fault zone at both ends of the segment. Incremental slip on the fault would be stimulated by injecting fluid into the fault zone through wells located between the two locked ends of the segment

The fault stimulation experiment would undoubtedly be tried along an uninhabited stretch of the San Andreas or on some other more isolated fault. Monitoring this experiment with Shuttle over passes might provide base data useful for recognizing imminent fault movement.

The hypothesis is that the pattern of heat distribution in or near large strike-slip fault changes throughout a day. An understanding of these changes in the vicinity of the San Andreas fault could aid in recognition of similar major structures using thermal methods, identify particular geologic hazards, aid in monitoring these large faults and perhaps contribute to methods for predicting movements.

### 3.5 Hydrology (H) Experiments



## SUMMARY EVALUATION

### H1. GROUND WATER DISCHARGE (SEEPS AND SPRINGS) AND MAPPING (USING PHREATOPHYTES)

The locating and management of water resources of earth will assume even greater importance than now (1972) in the 1980's. Ground water is a major source of water in many parts of the world's particularly arid regions. A Shuttle experiment in "applied earth science" using high resolution multispectral photographic systems to locate and map ground water sources and sinks would be a valuable contribution to water management programs in the 1980's.

The selective nature of the candidate experiment, utilizing, in part the serendipity capabilities of an awareness-trained man make this a valuable and useful experiment for Shuttle.

The overall Shuttle (MEO) rating of the experiment is Acceptable - Level 1.

# H1. GROUND WATER DISCHARGE (SEEPS AND SPRINGS) AND MAPPING (USING PHREATOPHYTES)

## 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

### 1.1 Associated Problem Areas

Water resource development and management.

### 1.2 Experiment Objectives

Inventory potential ground water seepages in areas where fresh water is important to the local population and where new sources could permit improved management and reduced cost distribution.

Identify the locations and growth cycles of phreatophytes (well plants) to assist in locating near surface ground water in arid regions.

### 1.3 Experiment Background

Ground water is discharged from the zone of saturation by the hydraulic process, or discharge into springs, streams, coastal waters, or small lakes or ponds. The locations of these seepage discharges are not well known and may be fairly periodic in nature. Knowing the location may permit the potential development of the resource and/or control of wasteful fresh water losses.

### 1.4 Proposed Technical Approach

#### A. Springs and Seeps

##### Flight Plan

- Select areas of the world with a recognized water resource problem but with known distributions of fresh water springs. (The various volcanic islands of the Pacific and Atlantic would provide ideal sites for survey).
- Plan early P.M. flights concentrating on the coastal regions (early P.M. will often permit clear sky viewing of the immediate coast because of the local circulation at the coast).
- Schedule launch during selected periods of potentially high, moderate and low water (potential) flow as determined from known springs.

### Sensors

- 10-12 micrometer thermal infrared radiometer (imaging) with a resolution of approximately 30 meters.
- High resolution camera with normal color film boresighted to image scanned area.

### Displays

- Buffered color CRT-type display IR scanner data together with graphics mapped displays showing the locations of existing springs within some specified distance of the coast.

### Analysis

- Straightforward mappings of the locations and "apparent volume" of the fresh water seepage. "Volume" can perhaps be derived from the area and its temperature.

## B. Phreatophytes

### Shuttle

The phreatophyte growing seasons are reasonably well known. A Shuttle mission with a high resolution multispectral scanner could be used to map the distribution of the various types of phreatophytes. If this mapping were done on a yearly basis the impact of various water use patterns on the ground water table could be assessed with some accuracy. Inventories of this type could be extremely valuable in countries where water is a valuable resource because of its limited abundance.

### Flight Plan

- 40-50 degrees inclination orbit
- Launch scheduled to provide clear skies over the areas of interest

### Ground Test Data

A number of test sites which contain a representative sample of phreatophytic species should be instrumented with spectrophotometers, shallow wells should be dug and the depth of water monitored.

### Sensors

- High resolution multispectral scanner covering the bands from blue to near IR. Resolution requirements of 15 meters.
- A high resolution camera (resolution 5 meters) should be boresighted with the scanner to provide corroborating imagery.

The initial flight of this experimental program should collect sufficient imagery and data to permit tests of multispectral automated techniques which would attempt to identify the various types of phreatophytic populations on the basis of texture and spectra. (Subsequent operational flights might be flown on automated satellites whereby only species information would be transmitted to the ground.)

#### 1.5 Relevancy of Experiment

- Location of fresh water sources.
- Identification of areas of fresh water loss.
- Underground water identification and mapping.

#### 1.6 Role of Man

- Identify
- Select
- Point
- Evaluate data

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

The precise pointing requirement inherent in this experiment will require a tracking telescope and stabilized gimballed sensor platforms.

#### 1.8 Supporting Research and Technology Required

Development of the sensor platform.

#### 1.9 Targets

- Coastal regions of volcanic islands
- Major rivers
- Brackish lake areas
- Vegetative regions in arid locations in the U.S. and in foreign countries

1.10 Truth Sites

- Known springs and associate seeps and discharges
- Two or three locations with known occurrences of various phreatophyte species.

1.11 Orbital Parameters

- 30-40 degree inclination
- 100-200 nautical miles

1.12 Data Required by Investigator

- High resolution "real" color film imagery.
- Concurrent thermal infrared data in imaged and mapped digital formats.

1.13 Principal Users

- Local/regional water resources managers.

1.14 Documentation/References

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

All seasons.

### 2.2 Frequency of Measurement/Observation

At least two times per mission.

### 2.3 Total Time Span of Measurement/Observation

5-7 days per sequence.

### 2.4 Solar Elevation Angle

45 degrees

### 2.5 Cloudiness

None permitted that would possibly prohibit photography.

### 2.6 Ground Coverage

50 nautical mile swaths along coast.

### 2.7 Resolution

- Photographic - 5 meters
- IR - 30-50 meters

### 2.8 Accuracy/Precision

- 1000 meters geographic location.

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
- High Resolution Multispectral Camera System  
(70 mm film)  
Six cameras (four B&W, color, and false color)

- High Resolution Wideband Multispectral Scanner  
(20 Spectral Bands)
- b) Correlative Support
  - Pointable Identification Camera
- c) Support Equipment
  - Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Displays
  - Tape Recorders.

## SUMMARY EVALUATION

### H2. MAPPING GROUND STATE - FROZEN OR NOT

The state of the earth's surface, i.e. whether it is frozen, saturated, dry, etc. is of immense importance to various earth scientists. For example, run-off of rainfall is nearly complete from frozen surfaces and increased water enters the drainage net as compared with periods when the soil could accept some of the water. Floods are often associated with the increased run-off. Numerical weather prediction requires surface state as an input.

The survey requirements for ground state mapping are extensive in area and resolution. Sensor systems must be multispectral. Radar has a great potential for discrimination of frozen from non frozen ground. Shuttle will be the first platform for high resolution SAR.

This experiment is important to several hydrological problems and is therefore rated Acceptable - Level 1 for Shuttle (MEO).



## H2. MAPPING GROUND STATE - FROZEN OR NOT

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Area

Locations of frozen and non-frozen ground.

#### 1.2 Experiment Objectives

Map the distribution and, as possible, the depth of frost in the ground at specific times of the year to provide necessary measurements for predicting water runoff as it may relate to floods.

#### 1.3 Experiment Background

The state of the ground is an important input parameter for flood forecasting models, numerical weather prediction models, etc. Information is currently quite erratic and while it may currently meet the needs of the weather prediction community, it may not be provided with sufficient spatial resolution to provide flood forecast model inputs.

#### 1.4 Proposed Technical Approach

An areas of the U. S. in the upper central plain area would be selected as a test site. This site would be surveyed, soils analyses made and instrumented with spectroradiometers, radiation thermometers, thermocouple strings in the ground to appropriate depth, etc.

The Shuttle experimental phase would be designed to collect data with a wide range of instruments. The ultimate objective would be to define a ground state mapping system for unmanned use.

Sensors would include:

- High resolution (3 or 4 bands) photography (resolution requirements: 5 meters)
- Coordinated high resolution thermal infrared (10-12  $\mu$  m band)
- High resolution radar images (SAR) as a test unit (100 meter resolution)
- Passive multi-channel microwave system to define brightness temperatures relating to the state change.

### 1.5 Relevancy of Experiment

Areal distribution of frozen and non-frozen ground.

### 1.6 Role of Man

- Select
- Evaluate
- Redirect

### 1.7 Impact of Experiment on Shuttle Sortie Mission

The volume of the SAR and its power requirements may be a constraint on the sortie mission package.

### 1.8 Supporting Research and Technology Required

No major requirements

### 1.9 Target

Test area in upper mid-west and surrounding region.

### 1.10 Truth Sites

Upper central plain test region.

### 1.11 Orbital Parameters

- $\geq 50$  degrees inclination
- 100-200 nmi.
- Circular

### 1.12 Data Required by Investigator

- High resolution film formats
- Digital tape from IR and scanners (IR and microwave)

### 1.13 Principal Users

- U.S. Corps of Engineers
- NOAA
- System designers

### 1.14 Documentation/References

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Spring

### 2.2 Frequency of Measurement/Observation

Once per day.

### 2.3 Total Time Span of Measurement/Observation

5-7 days.

### 2.4 Solar Elevation Angle

45 degrees

### 2.5 Cloudiness

None permitted

### 2.6 Ground Coverage

50 x 50 nmi test site area.

### 2.7 Resolution

Photographic	5 meters
IR Scanners	30-50 meters
Microwave Scanners	8 - 60 Km
SAR	100 meters

### 2.8 Accuracy/Precision

300 meters spatial location

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)

- High Resolution Multispectral Camera System  
(70 mm film)  
Six cameras (four B&W, color, and false color)
  - Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
  - High Resolution Wideband Multispectral Scanner  
(20 Spectral Bands)
  - Wideband Synthetic Aperture Radar  
(Wide Coverage, Low Resolution Mode)
  - Passive Multichannel Microwave Radiometer (PMMR)
- b) Correlative Support
- Pointable Identification Camera
  - Data Collection System
- c) Support Equipment
- Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Display
  - Tape Recorders.

## SUMMARY EVALUATION

### H3. SOIL MOISTURE MAPPING TECHNIQUE DEVELOPMENT

This candidate experiment has a prime objective to develop a sensor system for global and regional soil moisture mapping. The use of a large area, 50 x 50 miles, permits assessment of the moisture response of a variety of well defined soil categories and geologic under-structure. The passive multi-channel microwave system and radar will probably have their first space use on Shuttle. Initial studies may well be done from aircraft to develop the sensors to be flown on Shuttle. Since space-borne radar is essential for all weather coverage, space testing will be essential. Man will have a prime role in the program by reviewing the real time data onboard Shuttle and then possibly directing the mobile ground units to new locations.

This experiment is operationally important for future unmanned systems. High resolution is essential. In the test phase man is essential. The overall Shuttle MEO rating is Acceptable - Level 1.

### H3. SOIL MOISTURE MAPPING TECHNIQUE DEVELOPMENT

#### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

##### 1.1 Associated Problem Areas

Water management, ground water recharge, flood impact assessment, and hydrological model input.

##### 1.2 Experiment Objectives

Develop techniques to effectively monitor soil responses to seasonal flooding. As appropriate, apply those techniques to flood impact on areas such as Bangladesh.

##### 1.3 Experiment Background

Large areas of the world are subject to periodic and seasonal flooding. These floods extend over very large areas. Assessment of the response of the soils after flooding and mapping of the residual areas of standing water could provide data useful to various disciplines which are closely inter-related with hydrology, e.g., agriculture, flood forecasting, water management, long range weather forecasting, etc. Current techniques use empirical techniques to infer the large area heterogeneous response to large water inputs. This Shuttle experiment could provide a system, possible for eventual use on unmanned satellites, that could provide remotely sensed soil-response-to-flooding data.

##### 1.4 Proposed Technical Approach

Ground — An area of the U.S. which experiences seasonal flooding would be instrumented with soil moisture/temperature equipment in a fairly small grid mesh. Background data on geology, soils, vegetative cover and topography would be collected at each point in the grid mesh.

Shuttle — After occurrence of a flood in the instrumented region, the Shuttle would be launched to provide a period of high intensity, high resolution multispectral observation. Stationkeeping power would be used to provide continuous, once per day, observations for a 5 - 7 day period.

The proposed sensor complement on Shuttle would be:

- High resolution ( 4 - 6 band), multispectral, film return cameras with the focal length chosen to provide approximately twice the area of the test site
- Very high resolution, two-band (red and blue-green) with focal length providing only one quarter of the test area
- Multi-channel scanner providing visible, near IR and thermal IR
- Passive multi-channel microwave radiometer (4.99, 10.69, 18 and 37 GHz)
- X-band radar, synthetic aperture.

Onboard display of the scanner and radar observations would provide a means to direct mobile ground measurement or aircraft. The display format should provide the locations of the significant ground measurement sites. A linkage should be provided to permit display of the very high resolution camera pointing location on the image display system.

#### Operations -

- Following the initial passover, the test area during which all sensors would be on... the scientist would review the scanner data on the onboard display to define areas of significant interest... preflood imagery should be available for review by the scientist... If necessary, mobile measurement units or aircraft should be directed to the designated areas....
- On the next sequential pass the very high resolution camera should be directed into the area of interest
- Similar procedures should be followed for each pass, i. e., past pass onboard evaluation and mobile platform re-directed... the sensor operation mode could be altered as required by the scientist....

#### 1.5 Relevancy of Experiment

- Ground water recharge
- Engineering soils data
- Soil moisture distribution
- Flood impact assessment
- Soil moisture monitoring system development.

## 1.6 Role of Man

Man would serve as the onboard investigator and overall Project Director. He would select the targets, evaluate the results of observations, redirect the mobile ground truth stations as appropriate, and prepare detailed analyses of the data once he returns.

## 1.7 Impact of Experiment on Shuttle Sortie Mission

The pointing requirements will require a stabilized platform and linkage to a servo loop initiated by the tracking telescope.

## 1.8 Supporting Research and Technology Required

Development of onboard CRT displays patch-boards and onboard computer logic to permit certain levels.

## 1.9 Targets

Areas of the U.S. or abroad that are influenced by periodic flooding; e.g., the Ouachita River west of Vicksburg that was imaged by Apollo 9 and reviewed with Apollo and Nimbus data.

## 1.10 Truth Sites

- 1) Heavily instrumented grid centered on Ouachita River west of Vicksburg, Mississippi
- 2) Sylhet region of Bangladesh with increased instrumentation
- 3) Other suitable areas with potential population impact problems.

## 1.11 Orbital Parameters

Retrograde orbit, selected to provide daily coverage for 5 - 7 day periods over the same area. An alternate orbit might be one which provided a number of "looks" per day.

## 1.12 Data Required by Investigator

The scientist/astronaut would be designated as the Principal Investigator and would collect the types of data outlined under the Technical Approach. Designers of sensor systems for unmanned satellite to monitor soil moisture could use the sensor response and calibration information as they relate to the analyses and assessment of the investigator regarding soil moisture properties.



1.13 Principal Users

Hydrological engineers/agriculturists and system modelers.

1.14 Documentation/References

Nimbus Earth Resource Observations (NERO) by Allied Research Associates, Sabatini, Rabchevsky and Sissala (1971).

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Spring for experiment.

### 2.2 Frequency of Measurement/Observation

5 - 7 days sequentially.

### 2.3 Total Time Span of Measurement/Observation

Maximum of 3 - 5 minutes.

### 2.4 Solar Elevation Angle

45 degrees, if sun synchronous; variable, if a retrograde stationkeeping orbit is used.

### 2.5 Cloudiness

Less than 10 percent during test period.

### 2.6 Ground Coverage

Approximately 60 n. mi. frame or swath.

### 2.7 Resolution

Visible Systems	5 m
IR	35 m
Passive Microwave	8 to 60 Km
Active (Radar)	35 m

### 2.8 Accuracy/Precision

100 meter spatial.

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)

- High Resolution Multispectral Camera System  
(70 mm film)  
Six cameras (four B&W, color, and false color)
  - Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
  - High Resolution Wideband Multispectral Scanner  
(20 Spectral Bands)
  - Wideband Synthetic Aperture Radar  
(Medium Coverage, High Resolution Mode)
  - Passive Multichannel Microwave Radiometer (PMMR)
- b) Correlative Support
- Pointable Identification Camera
  - Data Collection System
- c) Support Equipment
- Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Displays
  - Tape Recorders.

## SUMMARY EVALUATION

### H4. SNOW AND ICE MONITORING STUDY

This study covers problem areas in contributions to snow and ice monitoring, multipurpose studies in Glaciology and in Water Management. The principal objective is to test whether an integrated system for monitoring snow and ice dynamics can be developed for world wide application, especially in the Antarctic and the Arctic latitudes. The experiment will involve 1) determining the extent, depth and water content of snow and monitoring its appearance and disappearance particularly in the northern hemisphere, and 2) monitoring glacial motion along the edges of the Antarctic Continent. Both the ERTS and Skylab experiments include studies on snow and ice. However, neither will have high resolution capability in high-latitude areas and neither will have the capacity to measure snow depth and contained moisture coupled with fine spatial resolution proposed in this experiment. On present indications a multi-frequency synthetic aperture radar may meet this requirement better than other instruments, although passive microwave systems will also be important as part of the experiment.

In order to achieve adequate calibration extensive ground instrumentation will be required and because of this the experiment, though of great value scientifically, and of considerable interest to the international scientific community engaged in studies in high latitudes, its rating is somewhat lower than its scientific interest would indicate. The Shuttle (MEO) rating is Acceptable - Level 1.

#### H4. ICE AND SNOW MONITORING STUDY

##### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

###### 1.1 Associated Problem Areas

Contributions to snow and ice monitoring, multipurpose studies in glaciology, water management.

###### 1.2 Experiment Objectives

The principal objective of this experiment is to test whether an integrated system for monitoring snow and ice dynamics can be developed for world wide application, especially in Antarctic and Arctic latitudes. The experiment will involve 1) determining the extent, depth and water content of snow and monitoring its appearance and disappearance, particularly in the northern hemisphere, and 2) monitoring glacial motion along the edges of the Antarctic Continent, land ice characteristics, contouring the ice surface of Antarctic, and observing the extent of iceberg calving, and mapping regional variations in crevasse patterns.

###### 1.3 Experiment Background

Both the ERTS and Skylab experiments include studies on snow and ice. However, neither will have high resolution capability in high-latitude areas and neither will have the capacity to measure snow depth and contained moisture coupled with fine spatial resolution. On the basis of present indications, a multifrequency synthetic aperture radar may meet this requirement better than other instruments, although passive systems also will be desirable in the experiment.

The first candidate platform suitable for a multifrequency radar will be Shuttle; thus this experiment is unique to Shuttle.

The degree to which radar (or passive microwave) penetrates snow and ice is a complex function of the temperature, contained moisture content, presence of mixtures of snow and firn, and the wavelengths of the system employed. This area has been sporadically researched for some time, as has comparable research in the passive microwave area. Considerable addition, R&D will be required.

An adequate study of ice and snow dynamics will require a knowledge of the following parameters:

- 1) Amount of snowfall (melted equivalent) in various areas.
- 2) Rates of ice motion along the edges of ice sheets and in glaciers.
- 3) The regional contours of the interior of major ice sheets such as those in the Antarctic continent, accurate to say 50 to 100 meters.
- 4) Detailed knowledge of ice types and extent of crevassing and regional variations in crevassing.
- 5) Extent of iceberg calving in areas around the ice sheet margins.
- 6) Degree of freeze and thaw in selected latitudes and altitudes during the summer months.

Most, if not all of these data may be obtained using a spacecraft system in conjunction with aircraft and ground data.

The amount of snowfall could be determined through fixed-wing aircraft drop of parachuted snow-depth probes together with manual placement using helicopters. The probes could be instrumented in such a way as to measure temperature and resistivity/conductivity which could then be converted to contained water at various depths in the partly buried probes. Latitude and longitude could be obtained initially through various procedures depending on the location, including use inertial navigation systems on the aircraft. Later measurements of snowfall would be made throughout the year through the snow depth measuring stations feeding data either to a central collection station that could retransmit to orbiting satellites or to the Shuttle spacecraft, or in some instances to ground stations.

The rates of ice motion and deformation of flow could be obtained through establishment of a pattern of transponders the original latitude and longitude which was known and in proximity to visible rocks which rise above the ice surface. Imaging of these areas during the course of the year with side-looking radar would then have a reference. The burial of transponders by snow should be of little consequence during the winter months. Experiments in the loss of signal after thawing would be needed prior to utilization of multifrequency radar system.

In selected areas, satellite navigation data could be obtained by a pattern of dropped satellite transponders. These could be of the simple type which could retransmit the doppler data either to Shuttle or to other satellites and then be analyzed on each polar mission. The accuracies of spatial and vertical location is sufficient with such satellite navigation systems (10 meters) so that movement and deformation of the pattern could be plotted through time in areas where ice/motion is fairly rapid. The rates of motion in selected regions could thus be obtained.

Regional contouring is desirable to enable the broad gradients of the continental ice fields to be established. It could perhaps best be obtained with a laser altimeter, although a radar altimeter would be at least as satisfactory except along the broken edges of the continent (Robin, 1967). The gradients thus established could be important in delineating the areas of most intense flow.

A detailed knowledge of ice types is potentially possible with multi-frequency radar, particularly along the continental fringe. Regional variations in crevassing also could be mapped under the snow cover, where fresh snow covers crevasses.

Iceberg calving could be monitored in successive missions using both radar and photographic systems.

The change in transmission characteristics of probes plus the variation in the radar return would be of value in delimiting areas where freeze-thaw takes place at lower elevations on ice sheets.

A broadly comparable setup could be developed for snow cover monitoring in high latitudes in Canada and Alaska. Probes could be all manually positioned if desired. The probes would be used to provide calibration points for snow depth/moisture content to be used in interpreting multifrequency radar images of various and differing drifting and depth histories. A systematic means for measuring snow depth characteristics of selected environments in the U.S./Canada would be an essential part of this experiment.

The aim behind the calibration experiments is to establish a basis for using the multifrequency radar for snow depth and moisture content mapping on a broad scale, with limited calibration/reference values.

#### 1.4 Proposed Technical Approach

The unpacking of the snow and ice dynamics will require analysis of data gathered by the following instruments:

- Side-looking multifrequency radar
- Laser altimeter
- Radar altimeter/scatterometer
- Cartographic Cameras
- Polarization Cameras
- Thermal IR Scanner
- Passive microwave scanning radiometer
- Tracking/photographic telescope
- Aircraft, helicopter, and ground placed ground instrumentation.

Polar orbit will be required  $\pm 4$  degrees; orbit times -- summer and winter solstices and two equinoxes.

Much of the system would operate automatically but the following would involve target acquisition and tracking by astronauts of areas of interests:

- High resolution photography using telescopes
- Photopolarimetry

In addition, the astronauts will have the normal switch on and calibration procedures for the instruments to be utilized.

The following roles are envisaged for each instrument:

Side Looking Radar - Delineation of regional and local flow lines, crevasses, ice types, sastrugi, thinly snow veneered rocks, the presence of snow covered moraines, regional variations in crevassing, calving of icebergs using time lapse imagery, snow depth studies on land and ice, etc.



Laser Altimetry - The laser altimeter proposed in the oceanographic experiments would also have some value in these high latitude studies. The altimeter could be used for fine scale altimetry and ice structure, and snow characteristics measurements. However, it would be an adjunct and not essential to the experiment.

Radar Altimeter - Scatterometer - The role of the radar altimeter would be to provide integrated regional profiles in Antarctica to produce regional contour maps for delineation of the ice surface. A relatively gross measurement such as this will be more satisfactory in the interior of the Antarctic than photographic systems: it is infeasible to level a photogrammetric model over snow fields. Along the edges of the continent where the ice breaks into individual glaciers radar altimetry will be too coarse and laser altimetry will be very helpful. Radar scatterometry will also provide supplementary data on regional variations in snow types particularly during summer months when freeze and thaw takes place.

Cartographic Camera - Moderate resolution cartographic cameras will provide data suitable for broad scale mapping on the continental edge of ice snow, water, and land surfaces. Triggered to coincide with laser altimeter pulses (which would be recorded by selected camera) the combination would yield quality mapping.

Polarization Cameras - A pair of matched cameras (black and white film) fitted with orthogonal polarization filters should be included as part of the experiment package. The multiple polarization capability will be tested for the detection of different types of snow (fresh, packed, partly thawed, drifted, strongly developed sastrugi, etc.). Sastrugi directions are important in delineating areas of persistent winds.

Thermal Infrared Scanner - There will be two principal roles for the thermal infrared scanner. The first is detection of locations of thermal activity. The second is that of radar crevassing studies. The strength of the wind in Antarctica is such that the thermal imagery might be wiped out at least a portion of the time by blowing snow.

Passive Microwave Scanning Radiometer - The passive microwave scanning radiometer (because of the generally low resolutions obtainable) would be used principally for broad area snow and ice characteristics mapping and would be usefully considered in conjunction with the radar scatterometer.

Tracking Photographic Telescope - Tracking photographic telescope will be employed by astronauts to obtain and hold for high resolution photography areas of interest discovered on previous missions.

Aircraft, Helicopter, and Ground Placement of Ground Instrumentation - The problem of servicing ground installations with adequate power over an extended time period is very severe in Antarctic. Despite this, however, a variety of instruments designed to enable us to know the exact location of the instrument, the temperatures of snow at various depths, contained moisture at various depths, and new snow fall contained moisture and related data will play an important part in such an experiment. The importance of the experiment will warrant a major program in developing suitable package instruments.

#### 1.5 Relevancy of Experiment

Major scientific information needs related to snow and ice budgets and movements would be addressed as well as major management problems on the snow budget.

#### 1.6 Man's Role

Man's role will vary depending upon the instruments from a considerable role in the early measuring of polarization phenomena and the use of the tracking telescope photography, and the calibration of instruments and the monitoring of instrument to obtain high-resolution performance.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

There would be considerable involvement of astronauts in monitoring and calibrating equipment, in acquiring high resolution photography using the tracking telescope in selected areas and at least initially in the use of a polarization differencing experiment. In the latter, two views of the same scene viewed through different polarization are presented to the observer at a rate such that flicker occurs in regions of variable polarization.

## 1.8 Supporting Research and Technology Required

Substantial reporting research and technology will be required in the following areas:

- 1) Development of suitable ground based instrumentation for placement in Antarctica, which is long lived, moderate rather than of great expense, may be positioned readily, may be interrogated easily from spacecraft, and has low power requirements.
- 2) The radar altimeter scatterometer, the passive microwave radiometer.
- 3) Polarization studies on snow and ice using aircraft.
- 4) Development of multifrequency imaging radars and a laser altimeter.

## 1.9 Targets

Snow and ice areas in various locations including high altitude locations in the tropics as well as Canada, Greenland and the Antarctic.

## 1.10 Truth Sites

The major ground truth sites should be established in areas of high accessibility where heavy instrumentation can be placed. These may include snow fields and glaciers in Canada, Greenland, and Alaska as well as the most accessible areas in the Antarctic.

## 1.11 Orbital Parameters

Polar orbits; altitude 150 nmi.

## 1.12 Data Required by Investigator

Ground truth data obtained by emplaced instruments together with notes of the conditions at the time of spacecraft passage.

## 1.13 Principal Users

NOAA (Sastrugi, iceberg, snow appearance and disappearance, depth and moisture contents), companies in mountain western U.S., Canada, Switzerland, New Zealand, etc.; glaciologists generally, the National Science Foundation Arctic and Antarctic program divisions, Office of Naval Research, etc.

#### 1.14 Documentation/References

Robin (1967)  
Simonett and Morain (1964)  
Simonett and Brown (1964)

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Two solstices and two equinoxes each for one week of observation.

### 2.2 Frequency of Measurement/Observation

Continuously in the appropriate latitudes during the week-long mission for instruments such as altimeters, radars, etc.; discontinuous observations with a tracking telescope depending on the need.

### 2.3 Total Time Span of Measurement/Observation

Few minutes per time of each telescope observation.

### 2.4 Solar Elevation Angle

Those prevailing at the time of the solstices and the equinoxes.

### 2.5 Cloudiness

Preferrably none. Radar and passive microwave data should be obtained even in the presence of clouds.

### 2.6 Ground Coverage

In addition to the experimental test sites, ground coverage should be obtained at the same time of as much as the Antarctic as is possible to enable a general contouring and mapping program to be carried out.

### 2.7 Resolution

Radar 15-30 meters; photographic systems 30 meters and in selected instances with the tracking telescope 5 meters; passive microwaves 8 - 60 kilometers; radar altimetry 25 meters (Robin, 1967), Laser altimetry 3 meters.

### 2.8 Accuracy/Precision

Pointing accuracy and location accuracy  $\pm$  300 meters.

## 2.9 Shuttle Instrumentation/Equipment Requirements

### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
- High Resolution Wideband Multispectral Scanner  
(20 Spectral Bands)
- Multifrequency Wideband Synthetic Aperture Radar  
(Medium Coverage, Low Resolution Mode)
- Laser Altimeter/Scatterometer
- Visible Radiation Polarimeter (VRP)
- Passive Multichannel Microwave Radiometer (PMMR)

### b) Correlative Support

- Pointable Identification Camera
- Data Collection System

### c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Displays
- Tape Recorder.

## SUMMARY EVALUATION

### H5. INTERNATIONAL SEASONAL STANDING WATER SURVEY

The principal objective of this experiment is to prepare on an annual, or as appropriate, on a seasonal basis, a survey of standing water in rivers, lakes, ponds, marshes, and treed swampland. Experiments would determine whether effective experimental and information gathering procedures can be developed to accommodate such widely differing environments as the low-latitude and high-latitude mountainous areas, arctic terrain, tropical rain forests and extensively cultivated regions. If an acceptable mixture of procedures can be developed employing multi-frequency radar imaging systems (potentially the most useful) and photographic systems, an international standing water survey would have incalculable benefits. These benefits would extend over health, agriculture, irrigation, hydroelectric potential studies and many other areas. The combination of tying together multi-frequency radar, for which Shuttle will be the first available platform, and sun glint and moon glint cameras in the experimental package make this experiment unique to Shuttle. It should enable first cut seasonal standing water survey performed with ERTS type satellites to be much more highly refined and to ensure that better management decisions on water resource can be performed. The Shuttle (MEO) rating is Acceptable - Level 1.

## H5. INTERNATIONAL SEASONAL STANDING WATER SURVEY

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas

Water management, hydrology, irrigation, agriculture, world health, water resources management.

#### 1.2 Experiment Objectives

The principal objective of this experiment is to prepare on an annual, or as appropriate, on a seasonal basis, a survey of standing water in rivers, lakes, ponds, marshes, and treed swampland. Initially, on an experimental basis, this would be done in selected environments. Experiments would determine whether effective experimental and information-gathering procedures can be developed to accommodate such widely differing environments as: low-latitude and high-latitude mountainous areas, arctic terrain, tropical rain forests, extensively cultivated regions in the mid-west, intensively cultivated areas in Europe, Southeast Asia, etc. If an acceptable mixture of procedures can be developed employing multi-frequency radar imaging systems (potentially the most useful) and photographic systems, an international standing water survey would have incalculable benefits. These benefits would extend over health, agriculture, irrigation, hydroelectric potential studies and many other areas.

The initial experiment objective, then, is that of a feasibility analysis as to whether a multi-sensor, multi-procedure detection and quantification of water areas can be developed which is internally consistent over a wide range of environments and circumstances.

In addition to the use of radar at look angles appropriate to the different environments, the use of sun glint and moon glint at low angles in broad plains and at high angles in tropical rain forests will need to be experimented with as part of the system.

#### 1.3 Experiment Background

While for many applications the quality of water in an area is critical information, there are a large number of applications for which a



simple knowledge of the distribution of water, either seasonally or at a given time of the year, or perhaps even bi-annually, is sufficient for a wide range of project management planning and water resource and development programs. Knowledge of the presence of standing water in open lakes and streams, in marshland, and under trees, would be of major importance in malarial control studies, irrigation and drainage projects, water control and diversion studies, and so on. The list is virtually endless.

Sun glint has been recommended as one procedure whereby updating can be achieved for water bodies, and certainly the use of sun glint would be one of the procedures to be used even though a constant angle of illumination would be infeasible because of variations of topography and density of tree cover. In the latter cases, however, high-sun angle glint is also feasible and could be used. A medium wave-length radar as portion of a multi-frequency radar system, should also enable discrimination (in the presence of different types of vegetation) of standing water bodies. It appears then that both sun glint and multi-frequency radar would be necessary on an experimental basis to determine whether an accurate catalogue and inventory could be made of water bodies. Cooperating experimenters throughout the world would undoubtedly be anxious to share in such an evaluation for the development of such an operational system would be a major contribution to national water management programs.

#### 1.4 Proposed Technical Approach

This experiment would require a one, or possibly a two-frequency focused synthetic aperture side-looking radar with a resolution of 15 meters. The two frequencies would be at 10 - 12 GHz and 3 - 6 GHz. In addition, a camera system designed to be manually as well as program-aligned to photograph sun-glint at various angles is required. The resolution of the camera system should be between 20 and 40 meters. Since both medium angle and high angle sun-glint will be required on an experimental basis, the experiment should be run at different local solar times for each of the selected test sites. The aim of the experiment is to determine through prior analysis, plus empirical testing or spacecraft, a suitable sun-glint and radar viewing angle to use both systems together at one time or on successive orbits, a day apart in sun-synchronous orbit. The combined use of both systems is initially to test whether sun-glint alone

is acceptable for most environments and whether radar may be required in cloudy situations, vegetated and mountainous areas. An unmanned operational satellite could employ a special sun-glitter camera and a single-frequency moderate resolution radar (30 meters) employing digital image processing in concert for an operational standing water survey. The test on Shuttle would be a feasibility test for a potential operating system in sun-synchronous orbit. The times of year recommended for test and ultimately for operational systems would be 2 equinoxes and the 2 solstices. In general, the experiment times, sun angles, and radar viewing angle will lie in the following bounds: early morning to mid-morning and late morning; radar angles of  $5^{\circ}$  to  $75^{\circ}$ ; radar depression angles of  $60^{\circ}$  to  $30^{\circ}$ .

#### 1.5 Relevancy of Experiment

Surface water extent for water management programs, seasonably obtained.

#### 1.6 Role of Man

- 1) To position glitter cameras for sun-glitter unless a computer and servo mechanism to do this is provided.
- 2) To calibrate and operate radar system.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

Will influence orbital parameters. Astronauts will need to position cameras in some instances and to attend to the performance of the radar when operating. Time of year constraints would involve the two equinoxes and solstices as well as early morning timing in critical areas.

#### 1.8 Supporting Research and Technology Required

- Development of sun-glitter camera
- Development of side-looking radar system (dual frequency required for marshland inventory)
- Testing of multi-frequency radars for optimum wavelength
- Testing of sun-glitter photography in various environments at selected sun angles

1.9 Targets

Various low and high altitudes, high and low latitudes.

1.10 Truth Sites

Rockies, Great Plains, Northern Minnesota, Florida, Central America, Amazon Basin, Alaska, Mid-Atlantic states.

1.11 Orbital Parameters

Orbit inclination  $60^{\circ}$ ; altitude 100-200 nautical miles.

1.12 Data Required by Investigator

ERTS - Type satellite map of selected areas of standing water.

1.13 Principal Users

Many government agencies concerned with water management conservation, electric power utilities, irrigation, health authorities, etc.

1.14 Documentation/References

Alan E. Strong and Irwin S. Ruff, "Utilizing Satellite-Observed Solar Reflections from the Sea Surface as an Indicator of Surface Wind Speeds," Remote Sensing of Environment, 1970, pp. 181-185.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

2 solstices and 2 equinoxes

### 2.2 Frequency of Measurement/Observation

4 times during the year for each site.

### 2.3 Total Time Span of Measurement/Observation

Few seconds each test site, each of 4 observations.

### 2.4 Solar Elevation Angle

Various,  $5^{\circ}$  to  $75^{\circ}$ .

### 2.5 Cloudiness

Nil for experiment, except in very cloudy areas where 10% cloud may be tolerated.

### 2.6 Ground Coverage

Total area to be mapped  $100,000 \text{ km}^2$ .

### 2.7 Resolution

Photography	20 - 40 m
Radar	15 - 30 meters
Sun-Glint Camera	300 meters

### 2.8 Accuracy/Precision

Pointing accuracy  $\pm 500$  meters.

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Multifrequency Wideband Synthetic Aperture Radar  
(Medium Coverage, Low Resolution Mode)
- Glitter Framing Camera

- b) Correlative Support
  - Pointable Identification Camera
- c) Support Equipment
  - Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Displays
  - Tape Recorders.

## SUMMARY EVALATION

### H6. ONBOARD SHUTTLE (ZERO-G) STUDY OF CAPILLARY MOTION OF WATER IN VARIOUS SOIL TYPES

Zero-G experiments which require the use of man for set up, data collection and analysis will be one general class of experiment which may be best performed on a manned Shuttle vehicle. In this experiment, some basic questions concerning the height to which water can rise in varying types of soils may be resolved.

This candidate experiment could prove very useful for improving modeling of soil moisture movement. Man is essential; zero-G is essential; therefore, Shuttle or a similar platform will be required. The overall rating for Shuttle (MEO) is Acceptable - Level 1.

## H6. ONBOARD SHUTTLE (ZERO-G) STUDY OF CAPILLARY MOTION OF WATER IN VARIOUS SOIL TYPES

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas

Hydrology, soil physics (specifically, soil water movement).

#### 1.2 Experiment Objectives

Evaluate, in zero-G, the height to which water will rise in soils due to capillary forces. Particular emphasis should be directed toward very fine soils, i.e., clays, where the theory is questionable.

#### 1.3 Experiment Background

According to the "capillary-tube hypothesis" the height to which moisture will rise in a thin tube filled with dry soil and in contact with water at the bottom is:

$$h_c = \frac{2F_s \cos \theta}{\rho_w r}$$

Where  $h_c$  is the height of the meniscus above the level of the liquid,  $F_s$  is the surface tension of the water,  $\theta$  is the angle between the meniscus and the water of the capillary  $\rho_w$  is the density of water and  $r$  is the radius of the capillary. Substituting average values for  $F_s$ ,  $g$  and  $\rho_w$  and assuming  $\theta$  equal to zero, the equation becomes

$$h_c = \frac{0.15}{r}$$

If this equation is applied to the extremely fine (pores) capillaries in clay, the equation yields questionable heights. Hence, various investigations have tended to modify the equation to yield limited moisture rise heights.

Laboratory studies on earth must be concerned with the effect of gravity on the soil moisture content and height rise.

If studies were conducted in a zero-G environment, improved understanding of the influence of gravity on soil moisture might be obtained.

#### 1.4 Proposed Technical Approach

##### Experiment -

- (1) Collect a number of known soil types and pack them into tubes. Assemble each soil type with a water reservoir in which a removable membrane separates the soil tube from the water.
- (2) Once in orbit the experimenter will remove the member so that the soil tube is exposed to the water.
- (3) The moisture rise will be observed at constant intervals (tube length will be chosen such that the rise height for five days can be carefully evaluated).
- (4) Prior to the spaceborne experiment, the same experiment should be conducted on the ground and the differences evaluated.

#### 1.5 Relevancy of Experiment

Capillary movement of water in soils.

#### 1.6 Man's Role

Initialize, monitor and evaluate the space and ground results.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

The scientist time requirements may be extensive. The rates of change in attitude will need to be controlled to minimize introductions of small gravitational forces.

#### 1.8 Supporting Research and Technology Required

Development of appropriate laboratory test equipment.

#### 1.9 Targets

Not applicable.

#### 1.10 Truth Sites

Not applicable.

#### 1.11 Orbital Parameters

No constraints.



1.12 Data Required by Investigator

Time lapse movies of the moisture rising in the capillary tube (dyes may be required) and quantitative measurements of the rate of rise.

1.13 Principal Users

Experimental hydrologists, soil physicist.

1.14 Documentation/References

2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

2.1 Time of Year/Season

Not applicable.

2.2 Frequency of Measurement/Observation

Throughout flight.

2.3 Total Time Span of Measurement/Observation

Throughout flight.

2.4 Solar Elevation Angle

Not applicable.

2.5 Cloudiness

Not applicable.

2.6 Ground Coverage

Not applicable.

2.7 Resolution

Not applicable.

2.8 Accuracy/Precision

2.9 Shuttle Instrumentation Equipment Requirements

Laboratory can with time lapse camera and other sensors.

#### H7. LARGE RESERVOIR CAPACITY AND SEDIMENT LOAD STATUS SURVEY

This candidate experiment will direct Shuttle-borne high resolution sensors to survey the capacity status and sedimentation of various major reservoirs. Emphasis would be directed to reservoirs in populated and unpopulated regions; e.g., the types of reservoir observed by Apollo 9 and ERTS-1 in the Dallas, Fort Worth area and those associated with Lake Volta, Nasser or the future Tarbella Dam holding reservoir (Pakistan). The data acquired periodically by the Shuttle could provide significant information to assist in future planning of water use, development of new techniques to reduce sedimentation, etc.

This candidate experiment is suited to high resolution from Shuttle. Man's aid is useful but not totally essential. The overall rating for Shuttle (MEO) is Acceptable - Level 2.

## H7. LARGE RESERVOIR CAPACITY AND SEDIMENT LOAD STATUS SURVEY

### OBJECTIVES

Monitor areas of large reservoirs for management planning data. Assess the rate and distribution of sedimentation in large reservoirs through the application of ground observation and high resolution remote sensors.

### BACKGROUND AND RELEVANCY

#### Capacity

The amount of water in storage in a reservoir at a given instant of time is an important data input to water management decision models. Current reserves must be accurately estimated. The accuracy of estimate is, however, a function of reservoir use. Hydroelectric reservoirs need to be maintained at a constant level in order that the volume of water and head through which it falls will be nearly constant. Flood control reservoirs need to be kept at as low a volume as possible and water supply reservoirs need to be held at a maximum level in periods of surplus such that the draw downs during use periods are maintained above certain critical levels.

#### Sedimentation

Rivers and streams entering reservoirs gradually add sediments to that reservoir until the reservoir eventually is filled. Sediment control procedures can be introduced:

- a) At the design stage when locations are being selected
- b) By design factors in the dam
- c) By mechanical removal after the fact.

Some approaches employ settling basins or vegetative screens at points up stream away from the reservoir to induce settling of the sediments before they reach the reservoir.

## TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

### Capacity

- o Ground Data Requirements – Surveys of the reservoir area conducted prior to the dam construction should provide a means to convert area to volume if the topographic analysis is accurate.
- o Shuttle – The Shuttle operation in this program is simple and straightforward:
  - a) The Shuttle objective is the rapid survey and mapping of one or more reservoirs in a given portion of the U. S. or other portion of the world
  - b) Times of operations are selected to conform to some predetermined set of decision points in the overall reservoir complex management model
  - c) Suggested sensors are high resolution metric mapping cameras providing 5 meter resolution with infrared film
  - d) Man's role in this type of inventory program is very limited. Perhaps the off-nadir coverage that might increase the number of reservoirs coverage in a selected time period would increase man's role. In general, however, man has a small contribution.

Standard aerial photogrammetric analysis techniques will be fully appropriate for the analysis activities.

### Sedimentation

- Select three different categories of reservoir; e.g., newly constructed, nearing design half life and heavily sedimented.
- If possible, select three or more analog reservoirs within which ground truth data can be collected.
- Make observations with 3 or 4 band multispectral cameras
  - Spatial Resolution     5 meter
  - Spectral Resolution   30 meterand 4 - 6 band scanner with approximately 30 meter spatial resolution and 150 millimicron spectral resolution.
- If an analysis equipment package is onboard, the scanner data can be evaluated and directions may be given to ground teams.

Man has a limited role in this investigation. He can perform some off-nadir observations and selectively choose targets for data collection sets.

## SUMMARY EVALUATION

### H8. REGIONAL AND LOCAL SNOW MAPPING

The periodic mapping of the distribution of snow and its hydrological characteristics (i. e., liquid water content, density, packing, melt zones, etc.) is essential for proper management of the water resource contained. ERTS will provide an excellent opportunity to collect data on the location of snow lines and the estimated depth (as derived from topographic features, tree coverage, area depth volume, etc.). ERTS will not provide water equivalent information. EOS may, in 1976, provide microwave measurement that are sufficiently useful to permit estimates of water equivalents. Shuttle will, however, offer the first opportunity to obtain combined photographic, passive microwave and radar data over large snow basins; such multispectral data may permit regional survey of water equivalents. The selective specialized nature of Shuttle may also permit survey of shadowed slopes, snow retained above forest canopy, etc. The resolution available from ERTS will not permit survey of snow retained in coniferous trees or stored beneath the canopy.

The prime objective of this experiment will be to direct the high resolution, multispectral capabilities possible from Shuttle to development of future concepts to be applied to unmanned satellites. The overall Shuttle (MEO) rating for this experiment is Acceptable -Level 2.

## H8. REGIONAL AND LOCAL SNOW MAPPING

### OBJECTIVE

To provide high resolution selective observations of locally significant variability in snow cover and hydrological characteristics.

### BACKGROUND AND RELEVANCY

Snow survey measurements are taken to assist in the prediction of water supplied. As is obvious, snow is a highly dynamic phenomena. Significant areas of snow cover may vanish in a few hours. A significant factor in snow survey is the amount of snow stored locally in erosion ditches, beneath tree canopies, etc. The 200 - 500 ft resolution planned to be generally available from unmanned resource satellites will not provide the required information.

### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

#### Flight Plan

Late Spring (e. g., early May) launch into orbit covering the areas of interest. In the U. S. the prime interest might lie in the:

- a) North facing slope courses, and
- b) Erosion patterns in the Upper Missouri River Basin and in various individual snow course areas.

40 - 50 degree inclination orbit should provide repeat coverage at various viewing angles.

#### Sensors

- High resolution cameras (five meter spatial)
- Multispectral passive microwave (mounted on a track and hold platform; i. e., long period IMC)

#### Analysis

- Standard photo-interpretation techniques to define snow area
- Application of current (1972) research program results to define the hydrological characteristics of the snow from passive microwave sensors.

### Shuttle Program

The Shuttle concept offers the opportunity to survey the regional and local snow distribution and hydrological characteristics with very high resolution sensors to complement the strictly regional and inherently low resolution observations from unmanned satellites.

The specific contribution of Shuttle would be in selective high resolution survey of known areas with search and hold scan capabilities for the passive microwave sensor systems.

### Man's Role

- Select targets
- Track targets
- Screen microwave images for review.



## SUMMARY EVALUATION

### H9. WATER INVENTORY

This candidate experiment is directed to the use of sun glint to permit regional mapping of surface water in regions where it may be difficult to achieve such mapping with more conventional approaches. Large areas of surface water do, in fact, occur over the U.S. that are not well known. The presence of open water is of importance to wild life management, fine grid mesh numerical prediction, etc.

This experiment is rated Shuttle (MEO) Acceptable - Level 3. The local nature of the specific proposal may restrict its acceptability. When combined with the International Standing Water Survey (H7), this experiment would be rated Level 1.

## H9. WATER INVENTORY

Effective planning and management of national fresh water supplies, development of flood forecasts, weather prediction, etc., all require fairly accurate inventories of surface water. Estimates are extremely inaccurate in forest covered areas and over much of the U.S. The proposed "glint" technique can provide excellent information on surface water areas for many areas of the world. This experiment would have as its objective the synoptic mapping of the distribution of surface water over the eastern U.S. over a 5 - 7 day period. Mission planning would require an orbit permitting the observation of surface water glint patterns through certain types of forest cover. Man's role would be to point the sun-glint sensor to achieve maximum glint as the sun-earth-spacecraft angular relationships change.

## SUMMARY EVALUATION

### H10. ICE DAM MAPPING

The candidate experiment has important disaster warning implications for some parts of the world; e.g., the Indus River upper reaches in the Hindu Kush Mountains. The survey nature of the candidate experiment, however, suggests that it could be added as an "if possible, turn sensors on" type of experiment. The collected data would be useful for assessing the possibility of conducting this type of survey.

The overall Shuttle (MEO) rating of this experiment is Not Selected, with the added proviso that Shuttle flights which pass over areas such as the Hindu Kush should be provided with film and maps which could be used if the astronaut/scientist mission work load permits.

## H10. ICE DAM MAPPING

Ice is often an indirect cause of serious and often devastating flooding. Ice dams may back up large volumes of water flooding river banks for miles upstream. In deep gorges the breaking of an ice dam can create havoc in the valley or reservoir below. Since the occurrence of ice jams and dams is generally limited to the Spring melt period, the use of Shuttle may appear possible. The proposed experiment aims to provide high resolution mapping of ice dams which may exist in inaccessible parts of the world. Concentration would be on those areas that could have a disastrous impact on heavily populated regions of the world; e.g., Pakistan and India.

## SUMMARY EVALUATION

### H11. SNOW PACK EVAPORATION (SUBLIMATION) MONITORING

This candidate experiment is directed to an important parameter in snow pack reservoir capacity assessment. There are questions as to whether the job can be done even with the best; i. e., 5 meter resolution officially allowable from Shuttle. If possible, significant new data could be gained to assist in snow pack water management.

This experiment is of interest; however, the question of whether it should be done with aircraft or Shuttle (if it can be done at all) and the limit on available resolution reduces the Shuttle (MEO) rating of this experiment to Not Selected. Data acquired in other snow mapping experiments from aircraft and Skylab should be carefully reviewed to fully assess the value of this experiment.

## H11. SNOW PACK EVAPORATION (SUBLIMATION) MONITORING

Substantial amounts of water stored in frozen forms are lost to the atmosphere through evaporation. The evaporation processes frequently create curious patterns in the snow called "sun cups" and "nieve penitente" which are various sized depressions distributed over the snow surface. The Shuttle-borne remote sensing program would be an attempt to map the distribution of evaporation patterns in order to assess the cumulative influence of evaporation of the snow pack. Measurements would be taken with a very high resolution camera.



## SUMMARY EVALUATION

### E1. MONITORING EFFECT OF CHANGING LAND USE PATTERNS ON WILDLIFE AND DOMESTIC LIVESTOCK HABITAT

There exists in many places in the world (Serengeti Plains, Pampas of Argentina, etc.) where natural grazing lands are receiving heavy use by domestic livestock where once only wildlife existed. The pressure threatens the integrity of existing wildlife preservation programs by reducing the areas available for natural wildlife, creating barriers to normal migration and increasing competition between domestic and wild herds. Shuttle observations could fill an important need by providing currently unavailable data on the dynamics of the land use changes and data useful to prediction of ultimate regional ecosystem effects.

This is a valuable experiment which can be only partially addressed by ERTS or other future systems. Man has a definite role in direct assessment of subtle factors. The experiment is rated Acceptable - Level 1.



## E1. MONITORING EFFECT OF CHANGING LAND USE PATTERNS ON WILDLIFE AND DOMESTIC LIVESTOCK HABITAT

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas

Regional management of livestock grazing, wildlife populations, and range habitat (cover types and conditions).

#### 1.2 Experiment Objective(s)

To study areas where rangeland habitat is experiencing heavy use (by wildlife and livestock) and pressure for changing use (agricultural expansion, growing rural populations) to determine:

- Areal extent of each important plant community
- Grazing intensity which each community will support (wildlife and domestic species)
- Areas of most intense pressures for competing land uses
- Areas needing immediate restoration from overgrazing
- Long term changes in land use and environmental quality (compare Shuttle imagery with ERTS and SKYLAB)
- Actual physiological and environmental factors influencing the animals (utilizing implanted sensors).

#### 1.3 Experiment Background

There exist many places in the world (Serengeti Plains, Pampas of Argentina, etc.) where natural grassland, shrubland, and pastures are receiving heavy use by domestic livestock, in which only wildlife was found before. The impact of growing agricultural development and resource extraction is greatest in terms of its effect on shrinking viable rangeland habitat.

For example, there exists increasing pressure by Masai tribesmen for more grazing and cropland in areas traditionally used by large herds of migratory wildlife in the Serengeti Plains. This pressure threatens the integrity of existing wildlife preservation programs by reducing areas available for natural wildlife habitat, creating barriers to normal migration patterns, and increasing competition between livestock and wildlife herds for relatively fixed quantities of browse and forage.

The role of Shuttle will be to:

- Obtain high resolution looks at threatened areas to assess the impact of changing (and more intensive) land use
- To provide updated information on land use changes and changes of environmental quality which have occurred since ERTS and SKYLAB data were analyzed
- To collect data from implanted sensors relating the remotely sensed data to local environmental conditions.

#### 1.4 Proposed Technical Approach

Obtain regional coverage of the areas involved with a moderate resolution (20 - 30 meters) camera system at specific times of the year when indicators of habitat condition are known to be most evident. Maps of current land use and patterns of natural vegetation can be prepared from this imagery. In addition, acquire high resolution (5 meters) imagery of selected sample areas within major habitat types. Ground documentation of the quantity, quality, and availability of browse and forage in these areas will be used to further quantify and evaluate these habitat types.

The following tasks can be performed:

- Make regional assessment of changing land use patterns
- Use habitat evaluations to estimate the size of wildlife populations which could be sustained in light of shrinking available habitat
- Recommend areas having highest priority for protection
- Locate areas most heavily damaged by overgrazing
- Herd size and composition might even be estimated from very high resolution imagery, especially for large mammals (elephants, giraffes, etc.) and their migration patterns could be studied using implanted telemetering sensors over extended mission periods.

#### 1.5 Relevancy of Experiment

- Changes in land use
- Grazing intensity and effect on habitat
- Estimate size of wildlife populations which specific areas can support
- Habitat conditions (degradation).

#### 1.6 Role of Man

Select targets of opportunity within target areas which exhibit transient phenomena (areas receiving rain, areas of heavy grazing known, etc.). Evaluate cloud cover over pre-selected sites for image acquisition.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

Tracking telescope use, CRT display evaluation and ground communication by scientist/astronaut.

#### 1.8 Supporting Research and Technology Required

- Animal instrumentation
- Tracking telescope development.
- SAR development for 15 meter resolution

#### 1.9 Targets

Selected rangeland areas experiencing conflicts in land use (wildlife versus farming, etc.) such as:

- Serengeti Plains
- Argentine Pampas
- Interior Australia.

#### 1.10 Truth Sites

Selectively chosen within representative habitat units where rangeland conditions, species composition, intensity of use, etc., are documented.

#### 1.11 Orbital Parameters

100 - 200 n. mi., 30 - 40 deg. desirable; 60 deg. acceptable.

#### 1.12 Data Required by Investigator

Moderate and high resolution imagery on standard film formats.

#### 1.13 Principal User(s)

In each geographical area:

- Wildlife managers
- Ranchers and farmers
- Government agencies responsible for settling disputes over priorities in land use, and in administering these lands.

#### 1.14 Documentation/References

1. R. N. Colwell, et al. Monitoring Earth Resources from Aircraft and Spacecraft, NASA SP-275, Government Printing Office, pp 1 - 170.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

As required at times of year when vegetation development is optimum for identifying important species and studying grazing use. The three examples chosen to illustrate this experiment (Serengeti Plains, East Africa, Pampas of Argentina, Lower Cape York Peninsula (Gilbert and Mitchell Rivers), Australia) all lie in the southern hemisphere. Two are tropical and the third (Pampas) is subtropical. Key times for sensing are as follows: October-November-December, April-May-June.

### 2.2 Frequency of Measurement/Observation

Probably two to four times a year.

### 2.3 Total Time Span of Measurement/Observation

One growing season or period of annual utilization.

### 2.4 Solar Elevation Angle

>30 deg.

### 2.5 Cloudiness

No cloud cover over test site.

### 2.6 Ground Coverage

Complete regional coverage (predetermined for each problem area) and subsample, high resolution imagery for selected subsample areas where accurate data is needed.

### 2.7 Resolution

20 - 30 meters for regional coverage; 5 meters for sub-sample imagery.

### 2.8 Accuracy/Precision

300 meters pointing accuracy.

## 2.9 Shuttle Instrumentation/Equipment Requirements

### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
- Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
- High Resolution Wideband Multispectral Scanner  
(20 Spectral Bands)
- Multifrequency Wideband Synthetic Aperture Radar  
(Narrow Coverage, High Resolution Mode)

### b) Correlative Support

- Pointable Identification Camera
- Data Collection System

### c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Displays
- Tape Recorders.

## SUMMARY EVALUATION

### E2. LAKE EUTROPHICATION: ASSESSMENT OF MAN'S ROLE

Land use practices and increased pressure on lakes in the United States and elsewhere have been causing dramatic increases in the rate of eutrophication. Rapid survey, at high spectral and spatial resolution, of various calibrated and non-calibrated lakes would provide significant data which may permit reduction of the eutrophication through changes in land use policies, restrictions on population increases in certain critical areas, etc. Shuttle MEO's ability to carry high resolution systems into orbit for short time periods is a distinct advantage; man's ability to abstract and recognize abnormal patterns may provide new insights into the patterns of lake eutrophication in various regions of the U. S. and the world.

The experiment rating for Shuttle MEO is Acceptable - Level 1.

## E2. LAKE EUTROPHICATION: ASSESSMENT OF MAN'S ROLE

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas

National and international water management. Also applicable to pollution and land use problems.

#### 1.2 Experiment Objectives

Monitor a series of "calibrated" and non-calibrated lakes in the U.S. and, as appropriate, in other areas of the world as a potential means for assessment of regional pollution and/or land use influence as it impacts on water management planning activities.

#### 1.3 Experiment Background

EPA is currently mounting an aircraft survey of 1200 lakes in the United States to assess the levels of eutrophication and probable levels of eutrophication and probable land use/pollution factors impacting on the lake. The EPA aircraft now based in Las Vegas will be employed in the survey effort.

Eutrophication of a lake is a natural occurrence, but man's activities accelerate the time scale over which it occurs. The rate of man's acceleration should permit the use of remote sensors to monitor it over a matter of years rather than centuries or decades as is the case with natural eutrophication processes.

#### 1.4 Proposed Technical Approach

Ground Truth — "Calibration" lakes located in areas of population impact and in wilderness areas should be instrumented and monitored beginning in the mid-70s. Instrumentation should consist of biological oxygen demand (BOD), sediment load, algae, currents, vertical temperature, etc., monitoring devices. Research teams should perform studies of the regions draining into the lake, analyses of the natural flora and fauna of the lake, etc. These baseline data could then be used to calibrate and threshold remote sensor observations from Shuttle.



- 1) Select area which includes the "test" lakes and "non-test" lakes
- 2) Plan orbit to permit repeat coverage with same sun-shuttle object geometry for period of flight; i. e., seven days
- 3) Prior to launch deploy personnel required at each test lake.

#### Sensors/Displays -

- 1) Multiband high resolution camera covering blue (blue-green), green and infrared. Resolution should be approximately 5 meters.
- 2) Imaging spectrometer with selective high spectral resolution imaging in the two or three bands which together can uniquely define chlorophyll distributions
- 3) CRT display which can provide inflight displays of the imaging spectrometer and thereby permit evaluation of specific lakes with selective high resolution camera observations
- 4) CRT with pointing display which presents location of primary test lakes.

#### Inflight Operations -

- 1) During initial pass over the area the cameras and spectrometers will be operating in a normal local nadir mode
- 2) The scientist will be selectively viewing the various test lakes with a very high resolution tracking telescope. The telescope will be driven by the guidance and navigation system to the immediate location to be searched and the scientist can do the final search. A camera attached to the telescope will permit the collection of non-metric annotation view of the test lakes.
- 3) On subsequent passes over the same area, the spectrometer may be directed to areas of interest defined by on-ground processing, inflight data review, etc.

#### Post-Flight Data Analysis -

- 1) Following the completion of each Shuttle flight over the test lake regions, the film data will be compiled into photomaps covering each lake region (more than one lake will normally be included in a region).
- 2) Specialized displays and mapping of lake "color", chlorophyll content, algal "blooms" as observed in the remote sensor data will be assembled as overlays to the photomaps

- 3) Detail evaluations integrating the ground truth data will be performed by the regional lake research teams to provide complete and concise analyses of the impact of various land use practices, sewage processing practices, etc., on the eutrophication problems.

#### 1.5 Relevancy of Experiment

Regional water management, regional land use monitoring, and regional pollution problem assessment.

#### 1.6 Role of Man

Conduct high resolution spectrometer survey, evaluate data and select areas within the lakes for further study.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

The data evaluation on-board will decrease the available time man can devote to other activities.

#### 1.8 Supporting Research and Technology Required

Establishment of a network of lake monitoring stations measuring biological oxygen demand, sediment load, algae, currents, vertical temperature, etc.

#### 1.9 Targets

Lakes in selected parts of the world.

#### 1.10 Truth Sites

Established in selected lake regions well prior to 1980.

#### 1.11 Orbital Parameters

To be defined on the basis of the areas of coverage. Generally inclinations will be less than 65 degrees. Altitude 100 - 200 n. mi. acceptable and desirable.

#### 1.12 Data Required by Investigator

Spectra and color photographs of calibrated and non-calibrated lakes and their environment.

### 1.13 Principal Users

Regional water management/land use/pollution management systems engineers and planners.

### 1.14 Documentation/References

1. "Global Effects of Environmental Pollution," edited by S. F. Singer, 1968. Published by D. Reidel Publishing Co.
2. "We are Witnessing Man-Made Eutrophication of Large Lakes," Dordrecht-Holland.

2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

2.1 Time of Year/Season

Spring and Fall

2.2 Frequency of Measurement/Observation

Two times a year.

2.3 Total Time Span of Measurement/Observation

Depends on lake size.

2.4 Solar Elevation Angle

45 degrees.

2.5 Cloudiness

Less than 10 percent over the lake.

2.6 Ground Coverage

Lake area.

2.7 Resolution

Spatial: 5 meters

Spectral: 0.015 micrometers

2.8 Accuracy/Precision

2000 ft. location; 10 ft. precision

2.9 Shuttle Instrumentation/Equipment Requirements

a) Primary Instruments

- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
- High Resolution Multispectral Camera System  
(70 mm film)  
Six cameras (four B&W, color, and false color)
- Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
- High Resolution Wideband Multispectral Scanner  
(20 Spectral Bands)
- Visible Imaging Spectrometer

- IR Multispectral Mechanical Scanner  
(Ocean Surface Temperature Measurement)
  - High Resolution Visible Imaging Spectrometer
  - High Resolution IR Multispectral Mechanical Scanner  
(Ocean Surface Temperature Measurement)
- b) Correlative Support
- Pointable Identification Camera
  - Data Collection System
- c) Support Equipment
- Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Displays
  - Tape Recorders.

## SUMMARY EVALUATION

### E3. WATER USE PATTERN - IRRIGATION

This experiment has unique "applied earth science" implications. Regional water system management may be required in the 1980s. Regions such as the Euphrates River covering Turkey, Syria and Iraq are closely interrelated and total system approaches to water use and management will be required to assure efficient utilization and minimize political tensions. Aircraft cannot effectively cover the region. Unmanned systems, like ERTS, will do a first-look survey of the area. Higher resolution and periodic specialized instrumentation coverage will be necessary in the 1980s. Man's role in selecting targets may be a paramount with future 5 meter resolution camera systems with narrow fields of view.

This experiment is important to the resource management program of the 1980s but the possible improvement of unmanned sensor systems and, therefore, prior accomplishment, reduce the overall rating somewhat. The Shuttle (MEO) rating is Acceptable - Level 1.

### E3. WATER USAGE PATTERNS – IRRIGATION

#### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

##### 1.1 Associated Problem Areas

Regional water management, regional irrigation management, agricultural system management.

##### 1.2 Experiment Objectives

- 1) Map the areas under irrigation from the Euphrates River in Turkey, Iraq, and Syria at four different times in the growing season
- 2) Identify crops, estimate yield, delineate irrigation problem areas.

##### 1.3 Experiment Background

The use of water for irrigation is a time and space varying phenomena. Observation of the use patterns as inferred from crop vigor and actual water locations for differing types of irrigation systems at various times of the year may provide information which is currently unavailable but is yet highly valuable for regional management of the irrigation systems.

##### 1.4 Proposed Technical Approach

Shuttle Program – The large areas covered by regional irrigation projects necessitate a remote sensing approach. The resolution requirements and periodic survey needs might support a 5-day surveillance by Shuttle.

Surveillance Objective – Map the crop areas under irrigation of the Euphrates River in Turkey, Iraq and Syria at four different times of the growing seasons for specified irrigated crops.

##### Flight Plan –

- 1) Plan flights to coincide with growing period of key irrigated crops
- 2) Choose orbit to provide maximum coverage for a 7-day period. For example a 30 degree inclination will cover major portions of the Euphrates on each pass day assuring some stationkeeping power

#### Inflight Sensors/Displays -

- 1) High resolution mapping camera with three or four band capabilities
- 2) Four or five channel scanner
- 3) Color CRT display for scanner output for selected bands
- 4) Small input buffered CRT display to provide enhanced images and ground or airborne processing of the multi-spectral data for crop type identification.

#### Inflight Operation -

- 1) On first pass over the region of interest, all sensors would be operating obtaining full coverage of the irrigated areas
- 2) During the period between passes the taped scanner data would be displayed for scientist review and selection of areas for detailed study
- 3) On subsequent passes over the target area, detailed investigations will be conducted of specific interest areas.

#### Ground Analysis -

- 1) After quality checks and electronic processing, the film images would be compiled into photomaps at some useful scale
- 2) Overlays would be prepared presenting the location of various crops and the pattern of inferred water use as derived from computer processing of the multispectral scanner and manual interpretations of the returned film
- 3) The compiled maps and overlays should then be published for review and use by each of the regional authorities in assessment of the efficiency of their particular water use practices.

#### 1.5 Relevancy of Experiment

- Irrigation practices
- Irrigation water distribution
- Irrigated crop yield estimates
- Overall regional water system management data



## 1.6 Role of Man

Man's role will be to sample the entire region, screen the imagery onboard and then make detailed observations of selected areas. Man's role is thus:

- Selection
- Evaluation.

## 1.7 Impact of Experiment on Shuttle Sortie Mission

Orbit selection to maximize coverage of specific management regions will be a potential constraint.

## 1.8 Supporting Research and Technology Required

- Onboard processor and displays
- User model to accept inputs.

## 1.9 Targets

- Irrigation activities throughout entire length of Euphrates River
- Reservoirs associated with various water development projects along the Euphrates River.

## 1.10 Truth Sites

- Selected test farms in Turkey, Syria and Iraq (selected by government representatives)
- Selected water management projects.

## 1.11 Orbital Parameters

- 30 - 45 degrees inclined (retrograde) orbits to provide at least five passes over the Euphrates
- 100 - 200 n. mi. altitude.

## 1.12 Data Required by Investigator

High resolution multispectral images (photographic) 9 x 9 inch format.

## 1.13 Principal Users

- Regional water project planners
- Regional and local irrigation project managers
- Regional and local market planners.

## 1.14 Documentation/References N/A

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Four times during a year.

### 2.2 Frequency of Measurement/Observation

Once per day; twice (AM and PM) if orbit permits.

### 2.3 Total Time Span of Measurement/Observation

Five to seven minutes per pass.

### 2.4 Solar Elevation Angle

40 degrees if once per day.

### 2.5 Cloudiness

Less than 10 percent permitted.

### 2.6 Ground Coverage

30 - 50 miles each side of Euphrates.

### 2.7 Resolution

Photographic sensors: 5 meters

Scanner: 30 meters

### 2.8 Accuracy/Precision

Positional: 300 meters

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
- Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
- High Resolution Wideband Multispectral Scanner  
(20 Spectral Bands)

- b) Correlative Support
  - Pointable Identification Camera
- c) Support Equipment
  - Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Displays
  - Tape Recorders.

## SUMMARY EVALUATION

### E4. ECOSYSTEM MONITORING IN NATIONAL PARKS OF THE WORLD

Management staffs of the world's national parks often may have insufficient information regarding the resources of their parks, the intensity of visitor use, the influence of external forces, and the changes taking place in the parkland ecosystem.

Shuttle may be able to provide a uniform base for assessing the global condition of the earth's unique natural areas. The appropriate world (UN) organization could analyze the Shuttle derived data from representative sites to assess global patterns in park resource condition and individual parks could request data for their own management purposes.

This is an important experimental program directly pertinent to the Spaceship Earth view of the 1980s. The overall rating is Acceptable - Level 2.

#### E4. ECOSYSTEM MONITORING IN NATIONAL PARKS OF THE WORLD

##### OBJECTIVES

- To allow the unique natural areas of the world (whether currently in park status or not) to be monitored regularly.
- To assess the extent of changes occurring in the ecosystems comprising these parks, and to determine whether these changes are "natural" or induced by man's activities (prevention of fire, introduction of livestock agricultural activities, excessive visitor pressure, etc.
- To provide impact data for making management decision--for the manipulation of both man and the landscape.
- To establish a worldwide repetitive assessment of the stability of the ecosystems being protected and to monitor these ecosystem on a global basis.
- To assess the size and condition of wildlife and waterfowl populations which use park areas, and to determine the long-term effect of these populations on the habitat.
- To identify those areas worthy of protection, especially those threatened with development or a reduction in natural values.

##### BACKGROUND AND RELEVANCY

Management staffs of the world's national parks often have insufficient information regarding the resources of their parks, the intensity of visitor use, the effect of external forces which compete for alternative use of parklands, and the changes taking place in parkland ecosystems. In addition, the worldwide status of ecosystem preservation is poorly understood.

Shuttle data should provide a uniform base for assessing the global condition of the earth's unique natural areas (as well as archeological sites). The appropriate world (UN) organization could analyze Shuttle data from representative park sites to assess global patterns in park resource condition, and individual parks can request data for their own management purposes.

##### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

- Obtain imagery of individual park sites, or samples of parks within large regions using a variety of sensors and resolutions, depending upon specific tasks (e.g., forest stand condition, species identification, vigor (condition, determination, etc.)).

- Establish a clearing center to coordinate requests from parks for data.
- Provide parks with either imagery (data) and/or partial analysis of imagery.

Man's role would be to:

- Coordinate requests and make onboard decisions regarding mission changes due to weather, other constraints.
- Perform onboard and earth lab data analysis.

## SUMMARY EVALUATION

### E5. FLOATING DEBRIS IN OCEANIC GYRES AND CONVERGENCES

Man is slowly discovering that he cannot continue to dump wastes into the oceans. Recent discovery of PCBs and the recent ties between DDT and PCB measurements (it is now thought that much of the DDT measured in penguins and other animals may be PCBs which could not be discriminated by the existing measurement techniques) suggest that the mapping of wastes, particularly mercury, PCBs, and other chemicals will be essential to ecological modeling. The sink for these wastes are the large gyres (e.g., the Sargasso Sea) and convergences of the world's oceans. The Shuttle, with high spectral and spatial resolution sensors, will spend extensive periods over the oceans. Man may well contribute considerable insight to the observed pattern of waste distribution and its influence on fisheries.

This experiment is important to the future monitoring of "Spaceship Earth". Unmanned systems will not have the required resolution. The Shuttle MEO rating is Acceptable - Level 2.

## E5. FLOATING DEBRIS IN OCEANIC GYRES AND CONVERGENCES

### OBJECTIVE

To predict the probable fate of floatables resulting from planned or unplanned ocean waste disposal.

### BACKGROUND AND RELEVANCY

The accumulation of floatable solid wastes disposed in the marine environment is becoming an increasingly significant problem. Recent oceanographic and other surveys have reported alarming accumulations of plastics and related materials in gyres and conveyence zones. In addition to the aesthetic problems, such materials may directly or indirectly influence biota. This is especially true where plasticizers such as PCBs dissolve and enter the food chain. If the plastic materials can be retrieved before much of the plasticizers are dissolved, a considerable threat to the ocean ecosystem may be reduced.

### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

High resolution sensors will be employed to monitor changes in known circulation patterns. High resolution microwave may also be useful for pinpointing exact regions of accumulation.

Man's role would be to perform onboard data analysis using, for example, additive or subtractive enhancement techniques with the microwave imagery to determine the presence and location of accumulation of plastic on the sea surface.



## SUMMARY EVALUATION

### E6. SEVERE STORM ECOLOGY EFFECTS IN COASTAL BAYS AND ESTUARIES

Hurricane Agnes, which recently affected the mid-Atlantic states, highlights the type of dramatic changes that can be introduced into the innumerable bays and estuaries of the U.S. East Coast and similar regions. Excessive fresh water input turns usually brackish waters into fresh water areas, shell fish such as clams and oysters cannot accept fresh water into their systems without massive kills. Fish larvae, normally growing in estuaries, are washed out to sea, coastal wet lands are inundated and salt hay and other natural grasses are damaged. The regions to be surveyed far exceed the effective capability of aircraft (from an economic viewpoint at least). The Shuttle, in an orbit that parallels the East Coast could provide extensive high resolution coverage. The effects are extensive and long lived and will tolerate a 10-day or so launch cycle for Shuttle. Man could be an extremely useful component in the survey by virtue of his ability to abstract useful information from masses of data, especially if he is aided by various onboard processors and displays.

The overall rating of this experiment is Acceptable - Level 2. The reason for Level 2 is the difficulty which might be encountered by the rarity of such large scale storms as Agnes.

## E6. SEVERE STORM ECOLOGY EFFECTS IN COASTAL BAYS AND ESTUARIES

### OBJECTIVES

To determine, on a regional basis, alterations of coastal morphology resulting from severe storms. A secondary objective would include the inferential determination of ecological consequences to coastal fisheries resulting from circulation changes, runoff, etc.

### BACKGROUND AND RELEVANCY

Winds and waves from severe storms frequently cause alterations in shoreline configuration resulting in changes in navigation channels and coastal and estuarine circulation, damage to coastal installations, and realignment or relocation of natural and artificial passes. Such ramifications occur on a gross scale easily detectable from orbital altitudes, but at present total impact must await comprehensive ground and aerial survey. Regional rather than local assessment should also aid in a coordinated relief and repair effort.

### TECHNIQUE, SHUTTLE APPLICATION AND MAN'S ROLE

Following occurrence of a major storm affecting a coastal region, the Shuttle will acquire high resolution imagery on a real or quasi-real time basis for analysis of the impact on the ecology of the coastal bays and estuaries. The mission will be designed for rapid return or long dwell times to acquire time series imagery for assessment of currents and sediment transport and deposition.

Major impact areas requiring immediate relief or engineering alteration, such as may be required to arrest channel blockage, can be identified by the Shuttle, with ensuing operations being directed from the Shuttle. Microwave imaging systems will allow such analysis before storm-associated cloud cover has dispersed. Early response may prevent such major disturbances as channel closing.

Man's role would include real time interpretation and direction, guidance, and coordination of post-storm response activities on the ground.



## SUMMARY EVALUATION

### OT1. ORTHOGRAPHIC MAP CONSTRUCTION FOR DEVELOPING AND DEVELOPED COUNTRIES: AN INTERNATIONAL OBLIQUE ILLUMINATION ORTHOPHOTO MAP SERIES

The objective of this experiment is to provide orthographic photo maps at a variety of scales for both developing and developed countries. With a mix of cameras of different resolutions available on Shuttle, it should be feasible to meet planimetric accuracy standards for constructing maps in the scale range from 1:24,000 to 1:250,000. It will not be possible to meet mapping accuracy standards for topographic mapping with the normally accepted contour intervals for these scales, using Shuttle as a collection platform. However, on an experimental basis for both Northern and Southern Hemisphere it should be possible through late afternoon photography to achieve the rough equivalent of normal northwest oblique hill shading for topography. For many purposes such shading when accompanied by gross and/or relative contouring would be acceptable. If more precise contouring were desired, a number of radar squint and interferometric techniques could also be employed.

This experiment would give an opportunity to test new approaches to meeting and updating national and international mapping standards over very large areas. It could lead to the development of an International, Oblique Illumination Orthophoto Map Series. A scale of 1:50,000 is suggested.

The opportunity to create new space products without being held to the constraints of systems, many of the limits for which have grown up over decades of tradition, is one which should not be ignored and which this particular experiment specifically addresses. A mix of high and low resolution spacecraft camera systems would be employed for this International Orthophoto Map Series. ERTS-type systems do not meet accuracy standards. Cartographic experiments on Skylab will address this problem to some degree.

OT1. ORTHOGRAPHIC MAP CONSTRUCTION FOR DEVELOPING AND  
DEVELOPED COUNTRIES: AN INTERNATIONAL OBLIQUE  
ILLUMINATION ORTHOPHOTO MAP SERIES

1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

1.1 Associated Problem Areas

Planimetric cartography, multi-disciplinary.

1.2 Experiment Objectives

The objective is to provide orthographic photo maps at a variety of scales for both developing and developed countries. With a variety of cameras with different resolutions available on Shuttle, it should be feasible to meet accuracy standards for constructing maps in the scale range from 1:24,000 to 1:250,000. Most, if not all, of the U.S. national mapping accuracy standards for planimetry should be capable of being met. For areas of national and international high priority, such photo maps with an overprint of updated cultural change should prove very valuable.

It will not be possible to meet national mapping accuracy standards from topographic mapping with the normally accepted contour intervals for the larger scales. However, on an experimental basis for both Northern and Southern Hemisphere, it would prove possible through use of late afternoon photography to achieve the rough equivalent of normal northwest oblique hill shading for topography. For many purposes such shading when accompanied by gross and/or relative contouring would be acceptable.

This experiment would give an opportunity to test new approaches to meeting and updating national and international mapping standards over very large areas. It could lead to the development of an International, Oblique Illumination Orthophoto Map Series. A recommended scale is 1:50,000.

1.3 Experiment Background

The experimental orthophoto map construction using Gemini 70 mm photography of the southwestern U.S. and Peru by the U.S. Geological Survey has indicated that a real potential is available for improving and regularly updating international cartographic quality mapping, using space photography.

The resolution and geometric infidelities of the RVB and MSS on ERTS satellites are such that they will not be able to meet requirements for accurate orthophoto map construction. Such products will, of course, be made with ERTS imagery, but the cartographic community looks forward with considerable anticipation to the use of cameras on Skylab. We know enough at this time to be confident that the Skylab experiments in updating existing maps through change detection and the construction of new orthophoto maps will indeed be successful. The pressure generated from this success will be an important ingredient in providing support for Shuttle high resolution camera missions.

Oblique hill-shaded maps are for many purposes fully as valuable as contour maps. We are confident that this space-series would fill numerous roles in planning and civilian use as yet unanticipated. Accompanied by slope population statistics for homogeneous regions, they could well replace topographic maps for many uses because of their graphic topographic display.

The convention of northwest illumination source (to avoid topographic reversals) would include the Northern Hemisphere, for at the Northern Hemisphere summer solstice  $\pm$  one month (May 21 - July 22), depending on the latitude, the sun sets north of west. Thus, in the range for a 10 degree illumination angle, the azimuths lie between 280 and 310 degrees for all Northern Hemisphere latitudes. A similar, suitable range of azimuths obtain in the Southern Hemisphere at the same time of year. An early morning (N. E.) illumination source is also feasible.

Coarse resolution cartographic cameras could provide the oblique hill shading. Cultural detail would be provided by high resolution systems.

Most users of topographic maps prefer rapid up-date of cultural detail for later issues of such maps, even at the expense of the normally minor topographic update. To meet this need the U.S.G.S. is moving to phased construction and issuing of updated topographic maps, beginning with orthophoto maps and ending with a revised topographic map. The proposed experiment is based on two premises:

- 1) That rapid update through orthophotography using 5-meter resolution systems will be welcomed by a high proportion of users and will satisfy many of the needs of the cartographic community

- 2) Oblique hill shading provided by relatively coarse resolution cameras (30 meters) plus low sun angle will, with accessory spot heights, be an acceptable substitute for contouring for many users.

The U.S.G.S. currently makes topographic map series only at the scales of 1:24,000 and 1:250,000 though earlier maps at scales of 1:62,500 and 1:125,000 are still available for selected areas. Most other countries publish maps at intermediate scales of 1:50,000 and 1:100,000. The appropriate scale for the international oblique hill shading photo map series would need to be chosen with the many users in mind. It is probable that a 1:50,000 series, which would in effect be a new scale for the U.S., would best meet both domestic and international objectives in such a mapping program.

#### 1.4 Proposed Technical Approach

In order for this experiment to be successful, the following combination of instruments and constraints will be desirable:

Cameras - 1) Cartographic quality, resolution 30 meters; 2) High cartographic quality, resolution 5 meters.

Time of Day/Year - Late afternoon or early morning summer solstice (Northern Hemisphere) for cartographic camera used to provide base and oblique hill shading. High-sun photography would also be used when available to provide cultural detail overprint.

The experiment would need to be repeated on a number of Shuttle missions in order to assess its feasibility. There is no doubt that given adequate repeat time, the dry lands and sub-humid lands of the earth could be covered in this procedure. The humid areas, especially in the tropics, will pose greater problems of cloud cover because of the later afternoon peaks in cloud cover; hence, the request for early morning imagery.

Significant points are:

- Oblique hill shading provided in binary, muted grey
- Ortho-photography in false color, real color, and monochrome
- Potential of updating of base every three to five years in areas of rapid change; 10 - 15 years in areas of slow to very slow change.

- Overprint of selected cultural detail, place names, etc.
- Early morning would give NE illumination; late afternoon would give NW illumination; morning is preferred because lesser cloud cover; the latter time follows cartographic convention for oblique hill shading.

#### 1.5 Relevancy of Experiment

Worldwide need for rapid updating of cultural detail and orthographic map series. Provision of oblique hill-shaded maps for areas that are unlikely to be contoured at detailed scale for many years.

#### 1.6 Role of Man

- 1) To engage targets in advance of nadir with tracking telescope. All cameras slaved to nadir of telescope as spacecraft passes over nadir.
- 2) To make decision regarding cloudiness, in relation to a record of previous coverage on clouds.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

Will need to meet time-of-year and sun angle constraints (early morning and/or late afternoon).

#### 1.8 Supporting Research and Technology Required

- 1) Development of tracking telescope
- 2) All other cameras are well within state of the art, but would need to be specifically designed.

#### 1.9 Targets

Initially, various targets selected in U. S. by U.S.G.S., thereafter selected foreign sites. For the purposes of developing reference missions, the following sites in the U.S.A. are proposed. They are representative of many topographic situations:

- 1) Mt. Rainier, Washington
- 2) Lawrence, Kansas
- 3) Harpers Ferry, Virginia
- 4) Boulder, Colorado.



#### 1.10 Truth Sites

See above.

#### 1.11 Orbital Parameters

Either sun-synchronous Northern Hemisphere summer solstice or, if this orbit is too high, program this photography on any mission within the range 120 - 200 n. mi. where portions of orbits meet the sun angle and general Northern Hemisphere summer conditions constraints.

It is not necessary that both coarse and high resolution photography be obtained at the same time. Indeed, there could be preferences for high-sun, high resolution photography and low-sun, low resolution photography, which would then be obtained at different times.

#### 1.12 Data Required by Investigator

From space: Cartographic quality photography, 30 m resolution  
High resolution photography, 5 m resolution.

From surface: Recently revised orthophoto map at various scales.

#### 1.13 Principal Users

- 1) If cultural detail and oblique hill shading is overprinted on on existing contours, these maps will be used by all existing users of contour maps
- 2) If cultural detail and oblique hill shading are provided for areas previously unmapped for topography at the scale employed, these orthophoto maps also will be used by most, if not all, users of topographic maps.

#### 1.14 Documentation/References

None.

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Northern Hemisphere summer solstice  $\pm 1$  month.

### 2.2 Frequency of Measurement/Observation

For experiment: One-time coverage for each area.

For operational system: As needed on a 3 to 50 year repeat cycle.

### 2.3 Total Time Span of Measurement/Observation

A few seconds for small areas covering 1:50,000 scale map areas, tens of seconds to minutes for large to very large areas, divided between several orbits and missions.

### 2.4 Solar Elevation Angle

10 - 15 degrees, late afternoon or early morning.

### 2.5 Cloudiness

Solid cover, 60 percent, leaving 40 percent completely clear; scattered cloud, 5 percent, or multiple coverage up to 30 percent cloud. (Clouds will be removed by digital techniques using multiple images.)

### 2.6 Ground Coverage

Initially four areas scattered around the U.S., with each the dimensions of a 1:250,000 scale quadrangle (1 degree x 2 degree = 5000 to 9000 sq. mi.).

### 2.7 Resolution

30 m for cartographic cameras; 5 m for high resolution cameras.

### 2.8 Accuracy/Precision

Nadir pointing 200 - 300 meters.

### 2.9 Shuttle Instrumentation/Equipment Requirements

#### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film

- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
  - Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
- b) Correlative Support
- Pointable Identification Camera
- c) Support Equipment
- Wide Angle Viewer/Hydrogen Alpha Line Viewer
  - Tracking Telescope
  - CRT Displays
  - Tape Recorders.

## SUMMARY EVALUATION

### OT2. INTERNATIONAL DEVELOPMENT PROJECT PRE-FEASIBILITY ANALYSIS

International lending agencies such as the World Bank, Asian Development Bank, United Nations Development Program, FAO, OAS, AID and other such programs grant funds for international project pre-feasibility analyses throughout the world, more especially in the less developed regions. The initial project evaluation prior to pre-feasibility analysis varies markedly from project to project depending upon the ability of consulting firms to obtain access to published data within the countries involved, and the recency and accuracy of maps, statistics, and other data available. As a result, some desirable projects may go unfunded because there are insufficient data to make an effective evaluation, or desirable projects provide unpleasant surprises during pre-feasibility and later analysis through inadequate and misleading data available at the time when the bank or the lending agency makes the initial evaluation.

The opportunity to obtain internally consistent high-resolution spacecraft photographic, infrared, and radar data at the earliest stages of planning or requesting for such projects would be very attractive to the major lending agencies. Indeed, the provision of such data as part of the requirements for documentation in support of such request for funding could emerge out of a successful experiment when tested through Shuttle. The principle involved is one of attempting to bring projects widely scattered in different cultures and times into a reasonably internally consistent format for evaluation through the provision of high resolution imagery. Pre-feasibility projects would involve geological, agricultural development, soil and forestry programs, programs for electrification, hydrologic surveys, dam construction, irrigation, works of agriculture and so on. In all of these, multi-stage sampling with high resolution data embedded in moderate and coarser resolution would be employed. The same data used to evaluate whether a pre-feasibility study was appropriate could in turn be used in the initial phases of the pre-feasibility in designing additional aircraft flights and/or spacecraft and ground data acquisition. The Shuttle (MEO rating is Acceptable - Level 1.

## OT2. INTERNATIONAL DEVELOPMENT PROJECT PRE-FEASIBILITY ANALYSIS

### 1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

#### 1.1 Associated Problem Areas

Multi-disciplinary principally background geological, agricultural, forestry and soil surveys, oceanographic (fishing) and estuarine surveys.

#### 1.2 Experiment Objectives

The objective of this experiment is to provide a high resolution, internally consistent data source in the form of satellite-obtained images over a wide range of international pre-feasibility projects. These could involve geological, agricultural development, soil and forestry programs and ocean-based development. These could include programs for electrification, hydrologic surveys, dam construction, railroad construction, irrigation, works for agriculture and preliminary surveys, all at the pre-feasibility level for which international funding is commonly sought by developing countries.

#### 1.3 Experiment Background

International lending agencies, though occasionally operating with short response time where they grant funds to client developing countries, tend generally to operate on a two-to-five year funding cycle in initiating projects. This is certainly the case with the United Nations Development Program and the World Bank and the Asian Development Bank, as well as the Agency for International Development. Other sources to which countries would turn include the OAS, FAO, etc. The managers of these international lending programs would, in conjunction with qualified data interpreters, assess the value of having internally consistent spacecraft-acquired data as part of the initial evaluation of a project.

Initial project evaluation prior to pre-feasibility analysis varies markedly from project to project depending upon the ability of consulting firms to obtain access to published data within the countries involved, and the recency and accuracy of maps, statistics, and other data available. As a result, some desirable projects may go unfunded because there are insufficient data to make effective evaluations, or desirable projects

provide unpleasant surprises during pre-feasibility and later analysis through inadequate and misleading data available at the time when the bank or the lending agency makes the initial evaluation.

The opportunity to obtain internally consistent high-resolution photographic infrared and radar data at the earliest stages of planning or requesting funds for such projects would be very attractive to the major lending agencies. Indeed, the provision of such data as part of the requirements for documentation in support of such request for funding could emerge out of a successful experiment when tested through Shuttle. The principle involved is one of attempting to bring projects widely scattered in different cultures and times into a reasonably internally consistent format for evaluation through the provision of high resolution imagery.

#### 1.4 Proposed Technical Approach

The approach is to provide high resolution data over a number of selected development project areas to obtain an initially consistent data base for evaluation prior to pre-feasibility analysis.

The cameras, imaging radar and multispectral scanners would be high resolution sensors, supplementing ERTS-unmanned satellite data, if available.

The principal role of the instruments is to provide a background of data obtained through image interpretation and computer processing of individual and multispectral channels which will lift the whole area of project evaluation to a new and higher level with both consistency and detailed information.

The same data used in the initial evaluation would be used as part of the pre-feasibility analysis, and in an ongoing program, would provide updated different material at later times both for monitoring and also to improve the whole pre-feasibility analysis. Requests for additional coverage (as new experimental requirements manifest themselves) could be initiated jointly by the international lending agencies and the countries concerned.

Coverage by side-looking radar will be independent of time of day, cloud cover and rain (exclusive of heavy rain conditions), thereby

increasing the opportunity to obtain data promptly to begin analysis. Frequent radar coverage will be the first obtained, followed by camera and multispectral coverage.

#### 1.5 Relevancy of Experiment

Need for improved data for international funding programs; improvement and support of pre-feasibility studies; improved feasibility studies.

#### 1.6 Role of Man

Instrument checkout, warm up, calibration, and monitoring; target acquisition and tracking with telescope.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

Would depend on locations selected (most would be relatively low latitude).

#### 1.8 Supporting Research and Technology Required

- Development of multispectral scanner with 30 meter resolution, 20 spectral bands desired
- Development of wide-band (50 MHz) synthetic aperture radar using multiple frequencies.

#### 1.9 Targets

Various, but especially from 30°N to 30°S latitudes. For the purposes of developing reference missions, the following locations and problems are given as examples:

- 1) Northeast Brazil (agricultural development), Rio Sao Francisco near Petrolina
- 2) Surinam (major rice development program), Coastal Strip East of Paramaribo
- 3) Ethiopia (irrigation project), Awash Valley
- 4) Morocco (hydro-electric project), Moulouya River
- 5) Zaire (major geological/mineral exploration)
- 6) West Irian, Headwaters of Digoel River (major railroad construction to serve mining areas in mountains).

#### 1.10 Truth Sites

As above.

#### 1.11 Orbital Parameters

Various: Altitude 150 - 200 n. mi. if possible; some high or low sun angle photography required; some need both.

For the individual locations the following are required for each site for radar illumination:

- 1) N. E. Brazil, >30 deg. radar illumination
- 2) Surinam, >30 deg.
- 3) Ethiopia, >30 deg.
- 4) Morocco, >30 deg.
- 5) Zaire, >30 deg. also about 10 deg.
- 6) West Irian, >60 deg., also 20 - 30 deg., and 10 - 15 deg.

Coverage by side-looking radar may be any time of day or night and under any condition of clouds or rain except thunderstorms, thereby substantially increasing the speed with which some data may be obtained for analysis.

Radar imagery with angles of 10 - 20 deg. is required also for Sites 1 and 5. Angles of 40 - 50 deg. depression are needed for Sites 4 and 6.

#### 1.12 Data Required by Investigator

Data collected in the process of making an evaluation of a loan application by an international lending agency.

#### 1.13 Principal Users

U. S. AID, U. S. G. S. Branch of International Geology, UNDP, FAO, OAS, World Bank, Asian Development Bank, etc.

#### 1.14 Documentation/References

A number of ERTS proposals were prepared with financial and other support from International Development Agencies.



## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Sites 1, 2, and 6 December or January; Sites 3, 4, and 5 April or May.

### 2.2 Frequency of Measurement/Observation

One time each instrument, each location.

### 2.3 Total Time Span of Measurement/Observation

Few seconds to several minutes per location, depending on size of area.

### 2.4 Solar Elevation Angle

>30 degrees. See also response under Section 1.11.

### 2.5 Cloudiness

Generally no problem for radar (except for clouds producing heavy rain); 10 percent scattered, 60 percent solid cloud cover (leaving 40 percent totally cloud free) for cameras, and MSS.

### 2.6 Ground Coverage

Various, depending on individual area to be covered; normally less than 5000 square miles. Of the examples given here, the areas involved are: Sites 1, 2, 3 and 4, 3000 square miles (30 x 100 miles); Sites 5 and 6 each 40,000 square miles (100 x 400 miles). High resolution sites all embedded in nadir of coarse resolution cameras.

### 2.7 Resolution

High resolution camera	5 m
Moderate resolution camera	30 m
Radar	15 m
Multispectral camera	30 m

### 2.8 Accuracy/Precision

+300 meters.

## 2.9 Shuttle Instrumentation/Equipment Requirements

### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Multispectral Camera System  
24 x 24 cm. (9 x 9 in.) film  
Six cameras (four B&W, color, and false color)
- Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
- Multifrequency Wideband Synthetic Aperture Radar  
(Narrow Coverage, High Resolution Mode)

### b) Correlative Support

- Pointable Identification Camera

### c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Displays
- Tape Recorders.

## SUMMARY EVALUATION

### OT3. INTERNATIONAL METROPOLITAN AREA BIENNIAL UPDATE PROGRAM IN URBAN PLANNING

Urbanization and metropolitanization continues apace throughout the developed and underdeveloped world. The less-developed countries are going through the same stage of urbanization and metropolitanization that the developed nations have gone through over the last 100 years. The pace is quickening, however, and the major capital investors involved in urban areas and their immediate regional surroundings point to these areas as locations for major planning and management decisions both now and in the coming decades.

By the 1980s the Census Cities Project in the U. S. and studies in Skylab with the Earth Terrain Camera will have indicated the role for high resolution cameras for small area studies on Shuttle. Any single city could probably be better studied using U2-type aircraft. However, when many cities located on many continents require coverage, an acquisition program of high resolution imagery (5 meters) comparable to that being obtained in the Census Cities Program in the U.S. today will be of immense value in government planning.

The uniformity of data bases will enable many procedures to be transferred between developed to less-developed countries. Regular updating every two years would enable imagery to be obtained coincident with the national census, ensuring that census data could be partitioned over the spatial information in the image and that the between-census periods would be adequately covered in the areas of rapid change on the rural-urban fringe. The wide scattering of locations, the relatively small areas involved, the repetitive coverage at frequent (yearly to biennial) intervals and the relatively high resolution required make this an experiment very specific to Shuttle. The Shuttle (MEO) rating is Acceptable - Level 1.

OT3. INTERNATIONAL METROPOLITAN AREA  
BIENNIAL UPDATE PROGRAM IN URBAN PLANNING

1.0 ELEMENTS OF EXPERIMENT DESCRIPTION AND DEFINITION

1.1 Associated Problem Areas

Urban planning, cartography, international aid programs.

1.2 Experiment Objectives

After an initial feasibility test, this experiment is designed to provide high to moderate resolution photography of the order of 5 to 10 meter resolution of metropolitan areas and very large cities suitable for urban planning functions. These resolutions would enable a single frame of 24 x 24 cm format to cover roughly 2500 sq. kilometers and 10,000 km<sup>2</sup> respectively. The comparable areas for a 70 mm format are approximately 250 and 1000 km<sup>2</sup> respectively.

The principal objective will be to provide at least every two years and preferably more often for major metropolitan areas and very large cities on a worldwide basis (especially in the developing countries), photography with a resolution suitable for broad scale urban and regional planning purposes. This photography would be of a type which might ordinarily be obtained from conventional mapping cameras carried at 20,000 meters; i. e., comparable to the standard RC-9 camera for the 24 x 24 cm format and the Hasselblad 70 mm for the smaller format.

This is an example of the library-type function in Shuttle. Repetitive updating would be programmed so that on many missions an appreciable number of metropolitan areas would be slated for coverage. The images will have many uses ranging from the production of urban and regional planning maps and land use surveys to population and traffic zone estimating during the years between censuses.

Indeed, many of the uses to which present hyperaltitude photography in urban areas is capable of being placed as indicated by Horton and others, would be feasible. The provision of an internally consistent data source in these images would enable rapid transfer between cities and nations of procedures for maximum data extraction. Training in both manual, analog and digital methods of data extraction would be feasible.

### 1.3 Experiment Background

The studies being carried on in the U.S. with RB 57F aircraft photography obtained by NASA, using color and false color photography of urban areas, has shown that photography with a resolution from 5 to 10 meters is eminently suited for many of the broader urban mapping and planning functions required by urban planners. The provision of such photography regularly on a national basis for the U.S. alone would be feasible using the high altitude aircraft now available. However, it would be infeasible on an international basis.

For a single city or even a moderate number of cities there would be no comparison between the high altitude aircraft and Shuttle as a flexible platform for obtaining exactly the information required. However, when considered over a span of two years with the many cities potentially involved on an international basis, the advantages quickly shift to Shuttle as a potential data acquisition platform.

The uniformity of acquisition scale and format should enable rapid transfer of interpretation methods and technology in handling and processing to developing countries for the production of and updating the whole range of products relating to urban areas: cartographic quality maps, land use maps, atlases of urban change, street development, usage of green space, population estimates between census years, planning for sewer and highway construction, partitioning of census data already aggregated over the spatial data in the images, city orthophoto map and many other products.

### 1.4 Proposed Technical Approach

This approach requires:

- 1) The coordinated use of a tracking telescope for acquisition and pointing at cities
- 2) Servo mechanisms to lock onto the city once acquisition of the same point is obtained (based on comparison with a previous photograph of the city)
- 3) Automatic triggering of a set of two or three cameras slaved to the tracking telescope when the selected sites are at the nadir.

Areas within cities where rapid development is taking place or where some emergency action may be required could be viewed and photographed more often than every two years. U. S. Cities could be viewed seasonally to maximize the ability of the astronaut, when presented with a folder of previous seasonal photographs, to recognize newly visible information provided by such changes as leaf-kill, fall coloration, spring growth, urban pollution, etc., and use his judgement to obtain more frequent photography.

For a few selected cities, repeated observation with changing conditions would be desirable; e.g., Washington, D. C., on all missions at whatever sun angle whenever a mission passes during daylight over the city. In an equatorial orbit numerous images could be obtained of a city such as Belem or Quito.

#### 1.5 Relevancy of Experiment

International urban planning requirements.

#### 1.6 Role of Man

Acquisition, pointing, triggering of slaved cameras; comparison visually with previous photographs; rejection of photography for reasons of cloud cover, etc.

#### 1.7 Impact of Experiment on Shuttle Sortie Mission

Would require acquisition of cities and triggering of camera mechanisms by astronauts.

#### 1.8 Supporting Research and Technology Required

Tracking telescope development with associated lock, servo-mechanisms, slaving of several cameras.

#### 1.9 Targets

Initially, cities in excess of 1,000,000 people. At a later time, this figure could be dropped to 250,000 for selected areas.

#### 1.10 Truth Sites

First experiments: Census Cities (10 percent rank size sample) of U. S. used in the NASA Program. Follow-on experiments: Sample cities in Australia, Latin America, Africa, etc., as negotiated between foreign governments and the U. S.

For the purpose of developing a Shuttle reference mission, the following cities may be used:

U. S. A. — Washington, D. C.; San Francisco, California; Boston, Massachusetts; Seattle, Washington; Dallas-Fort Worth, Texas; Kansas City, Missouri; Los Angeles, California; Chicago, Illinois; St. Louis, Missouri; Houston, Texas; New York, New York; Pittsburgh, Pennsylvania; Denver, Colorado.

OVERSEAS — Sydney, Australia; Calcutta, India; London, England; Sao Paulo, Brazil; Buenos Aires, Argentina; Santiago, Chile; Mexico City, Mexico; Montreal, Canada; Djakarta, Indonesia; Capetown, South Africa; Madrid, Spain; Teheran, Iran; Ankara, Turkey; Algiers, Algeria.

#### 1.11 Orbital Parameters

Various; preferably altitudes near 150 n. mi. with 100 - 200 n. mi. acceptable. The orbital parameters for other experiments could be used to acquire many, if not all, cities in this experiment. Since many cities are to be covered, any Shuttle mission could target a variety of cities, depending on the orbits selected for other experiments.

#### 1.12 Data Required by Investigator

Most recent maps and photographs of the cities involved on an experimental basis. Later, the imagery would be supplied direct to the city planners for their interpretation.

#### 1.13 Principal Users

Metropolitan centers, state governments, planning departments, federal government departments, international agencies, private developers, transportation authorities, census, etc.

#### 1.14 Documentation/References

Horton (various reports to and within U. S. G. S. Geography Applications program)

Wray (various reports to and within U. S. G. S. Geography Applications program)

Alexander (various reports to and within U. S. G. S. Geography applications program).

## 2.0 MEASUREMENT/OBSERVATION/DESCRIPTION/REQUIREMENTS

### 2.1 Time of Year/Season

Any time, low altitudes; seasonally in mid-latitudes. All mid-latitude cities covered for the first time will have four seasonal photographs. Initially, this will be only with U. S. cities. Thereafter, other cities will be covered in the seasonal photographs.

Early Shuttle missions thus will accept photography of any date for all cities.

### 2.2 Frequency of Measurement/Observation

Every two years minimum; up to eight times in two years initially for selected cities is desirable.

### 2.3 Total Time Span of Measurement/Observation

Each city, each observation from a few to approximately 30 seconds.

### 2.4 Solar Elevation Angle

Mostly above 30 degrees; for a selected few U.S. cities, on a test basis sun angles of 10 degrees will also be studied.

### 2.5 Cloudiness

Cloud free or essentially so. This will, therefore, require repeated viewing and data takes by the astronaut to achieve this condition.

### 2.6 Ground Coverage

Various; depends on city and surrounding area desired by metropolitan planning agencies. Normally, for the following sensors:

Coarse resolution camera (20 meters):  $40,000 \text{ km}^2$

Moderate resolution camera (10 meters):  $10,000 \text{ km}^2$

High resolution camera (5 meters):  $2,500 \text{ km}^2$

### 2.7 Resolution

20, 10, and 5 meters, depending on camera system.

### 2.8 Accuracy/Precision

Pointing to within 200 meters.



## 2.9 Shuttle Instrumentation/Equipment Requirements

### a) Primary Instruments

- Panoramic Camera  
12 cm. (5 in.) film
- Wide Angle Framing Camera  
24 x 48 cm. (9 x 18 in.) film
- Multiresolution Framing Camera System  
24 x 24 cm. (9 x 9 in.) film  
Three cameras, false color film only
- High Resolution Wideband Multispectral Scanner  
(20 Spectral Bands)

### b) Correlative Support

- Pointable Identification Camera

### c) Support Equipment

- Wide Angle Viewer/Hydrogen Alpha Line Viewer
- Tracking Telescope
- CRT Displays
- Tape Recorders.

## SUMMARY EVALUATION

### OT4. INTERNATIONAL ARCHEOLOGICAL SURVEY

The experiment objectives are to determine initially whether combinations of low, medium, and high resolution photography obtained at a variety of sun angles, and whether multi-frequency radar with a multi-resolution capability provides opportunities to detect archeological sites. This experiment, though of considerable interest, would be an add-on experiment regions which are archeologically sterile in underwater and could be diverted to under-water parks. On the land, deliberate experimental models could be set up in detecting known but difficult-to-observe features on the ground.

As the 21st century approaches, tourism becomes an increasingly important part of the foreign exchange earnings of countries with significant archeological sites. If discoveries of significant archeological sites were to be made with spacecraft data, there would be considerable international impact from such discoveries. The problematical basis of the study requires that it be an add-on with a Shuttle rating of barely Acceptable - Level 2.

## OT4. INTERNATIONAL ARCHEOLOGICAL SURVEY

### OBJECTIVES

Initially to determine whether combinations of low, medium, and high resolution photography obtained at a variety of sun angles and multi-frequency radar with multi-resolution capability provide opportunities to detect archeological sites which have only recently been discovered. There are two parts to this project: a land archeological survey and an underwater archeological survey. The principal experimental areas initially would be in the countries fringing the Mediterranean Sea and in the jungle areas of Central America.

### BACKGROUND AND RELEVANCY

It is well known that the early use of aerial photography inadvertently discovered and identified major finds of Roman and Celtic ruins, cultivation patterns in Britain. Over the last three decades, many such finds have been made and documented. We may reasonably anticipate that some of the high-resolution low-sun angle photography and radar imagery obtained on Shuttle would also enable such features to be detected on a somewhat larger scale. A similar situation has been found in underwater photography from aircraft, where chance photography has shown the presence of a variety of underwater archeological remains, including buildings and sunken vessels. The directors of antiquities in most of the Middle Eastern, Southern European and North African countries have become very conscious in recent years of the need to preserve their underwater archeological remnants from poaching. Thus, in Greece, only three very small areas are now open to scuba diving. In order to satisfy the need for developing underwater parks on an international basis for tourism and an equivalent international thirst for archeological exploration, a Shuttle underwater survey around the Mediterranean involving the use of special films for maximum water penetration appears desirable. Areas which are archeologically sterile, as indicated on space photography and as confirmed with selected sampling studies, might then be eliminated from restrictions to scuba diving and could be converted to international scuba parks. Areas of potential interest could then be concentrated on by other means for archeological search.

On the land, deliberate experimental models could be set up for detecting known but difficult-to-observe features on the ground. The use of multi-frequency radar could be of considerable significance in this regard in the desert areas, the dry land areas, and around the Mediterranean during the Summer season, and also in the tropical rain forest in Central American where there is reason to anticipate major archeological finds using multi-frequency radar.

As the 21st century approaches, tourism will become an increasingly important part of the foreign exchange earnings of countries with significant archeological sites. If discoveries of significant archeological sites were to be made from spacecraft-acquired data, there would be considerable international impact from such discoveries.

#### TECHNIQUE, SHUTTLE APPLICATION AND ROLE OF MAN

The requirements for this experiment include:

- Two cameras with resolutions of 5 - 10 meters, slaved to a zoom telescope
- A single frequency side-looking radar, 30 degree depression angle, resolution of 15 meters
- High-resolution thermal IR scanner.

On orbits which pass over the sites, photography with a variety of sun angle will be obtained to see whether disturbed ground and geometric structures which have been documented on the ground can be detected, and whether new relationship can be discovered using the various illumination angles.

Pre-dawn thermal IR scanner imagery will also be obtained to detect disturbed ground or altered tree growth.

Side-looking radar will also be employed on suitable orbits to ascertain whether features of known archeological significance can be detected.

For the underwater archeological study, cameras fitted with special films for water penetration and low-light conditions will be utilized. Initially, the sites to be inspected should be already well documented cases.

Man's role would include the acquisition of sites, pointing of zoom telescope, triggering of the slaved camera set, monitoring performance, and calibration of radar and thermal systems.